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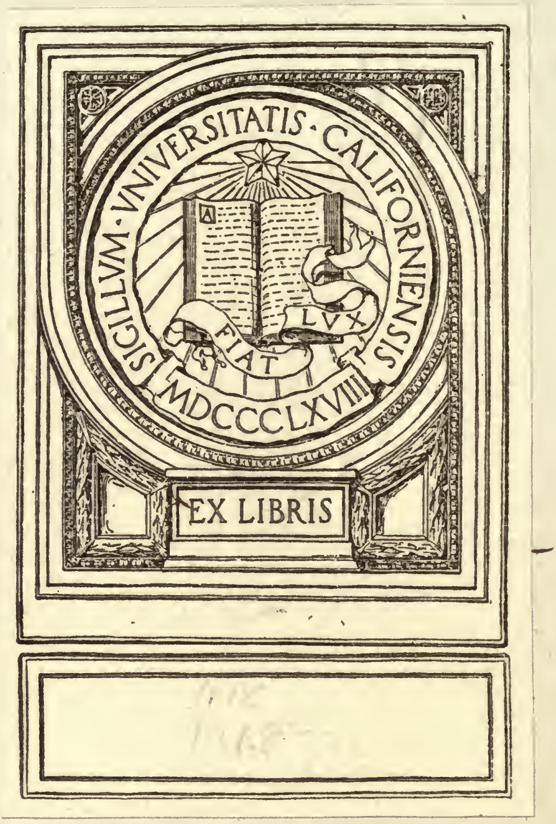
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LAND DRAINAGE

A Treatise on the Design and Construction of Open and Closed Drains

By

J. L. PARSONS

ASSOCIATE MEMBER OF THE WESTERN SOCIETY OF ENGINEERS

UNIV. OF
CALIFORNIA

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PREFACE

Land drainage at the present time has assumed an important place among engineering enterprises. While the existing literature upon this subject is excellent, the amount is limited and much of the information that should be available to those connected with the design, construction, maintenance and general administration of drainage enterprises is either not in publication or has not been sufficiently discussed and proven by experience and experiments. The author offers this treatise upon this subject with the hope that it may be of value in the development of the science of land drainage.

To young and inexperienced drainage engineers: Especial efforts have been put forth through the medium of these pages to acquaint you with the problems that you must meet; to impress upon you the importance of accuracy, judgment, honesty and diligence in the investigation and solution of these problems, and to suggest methods of procedure under average conditions and the general principles upon which to base conclusions and plans.

To experienced drainage engineers: The author hopes for a careful and analytical reading of these pages by you and that some of you will be thus incited to take issue with or elaborate upon the questions discussed and thus aid in the formulation of better drainage standards.

To drainage contractors: The author has recognized the facts that contractors have been compelled too often to contend against such unfair conditions as incomplete surveys and reports; the framing of specifications so as to burden contractors with the risks resulting from insufficient plans, and treacherous soils and unfavorable weather conditions, and has pleaded for justice and equity to contractors. Neither have the faults and obligations of contractors been overlooked. Also information is included which will prove useful to contractors, and it is suggested that a general study of the subject of land drainage would better enable contractors to protect their rights and succeed in their business.

To land owners and drainage district officials: The author believes that a general understanding of land drainage science by you would enable you better to distinguish between the efficient and the incapable in employing drainage engineers and to assist and advise with them in the direction of the work which is of such great importance to the agricultural interests of the United States and thus accomplish more effective land drainage.

In conclusion, this treatise has been made as complete as possible for the subjects connected with the successful drainage of agricultural lands by open and closed drains. The author hereby acknowledges a large amount of valuable information which has been gleaned from the reports of the United States Department of Agriculture, from reports of state and other colleges, from the reports of engineering societies, and from engineering periodicals. Specific reference has been made in all cases where important data have been reproduced.

Humboldt, Iowa, 1914. J. L. PARSONS.

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LAND DRAINAGE

CHAPTER I

PRELIMINARY DRAINAGE SURVEYS

Purpose of Preliminary Surveys.—A thorough preliminary survey is of primary importance to the inception, construction and maintenance of all drainage enterprises, whether they are small farm systems, or the larger drainage districts affecting extensive areas of land, and costing many thousands of dollars. This survey is the basis of the design and construction of costly improvements which by all standards of justice and economy should be reasonably permanent. An erroneous or incomplete survey is disastrous to the reputation of the engineer, to the economic success of the drainage system, to the constructing contractors, and, generally, to the good name of land drainage. The first corrective step against such possible failures is a complete and efficient preliminary survey executed by a qualified drainage engineer. Such a survey consists of the collection of all essential data and their mapping and collation in a form suitable for designing purposes; for purposes of future reference in cases of repairs, extensions and scientific investigations; for the preparation of suitable specifications and contracts, and for the presentation of reliable information in cases of legal complications. The object of this chapter will be to discuss some of the methods of approaching the ideal survey, the attendant obstacles to the accomplishment of the ideal, and proper procedures under various limiting conditions.

Object of Preliminary Surveys.—An engineer engaged in drainage engineering practice is subject to employment for a number of purposes. He may be engaged by a land owner: (1) simply to make a level survey of a tile line or a system of tile lines, determine the available fall, and furnish the necessary figures for the depths of tile, the sizes of tile, location of tile lines and maximum depths being prescribed by the owner; (2) to lay out and design a system of drains for a parcel of land from data that may be acquired by a few test levels and a general eye-examination of the land; or (3) to properly survey the lands and design a drainage system, being free to secure necessary information by surface and soil surveys in detail. In cases of legal organizations of drainage districts, he is appointed by the authorities, to whom the appointive power is delegated, to make a preliminary survey of larger areas of land, design system of outlet drains, and make reports according to the requirements of law.

Methods of Conducting Private Surveys.—Although a working knowledge of the fundamentals of drainage practice is essential to the engineer employed in the prosecution of preliminary drainage surveys of any kind, such knowledge is especially necessary in the case of private surveys. This is true because of the fact that the greater percentage of direct land reclamation is accomplished by lateral drains, the main drains serving only as outlets for them, and also because in much of the work decisions must be made, plans formulated and suggestions made in the field, with little opportunity for office investigation. To insure efficient drainage, competent engineers should be employed, but it has been too generally true that inferior surveyors have been employed to prosecute this work, partly because land owners have been unwilling to pay for competent surveying, and partly because engineers have not been available when desired, because of this lack of support.

In the first of the above cases, the engineer is handicapped, because of ignorance or false economy, in the proper accomplishment of his work. In lieu of properly acquired data he must exercise intelligent observation, inquiry and tactful suggestions in order not only to insure successful tile drains so far as possible but also to discharge his professional duty of impressing upon the owner the economic necessity of properly directing drainage work. While effecting such a survey the engineer should make an eye-examination of the land and at least suggest a practicable scheme of drainage if it appears that the proposed plan is likely to prove unsatisfactory. This examination should approximately determine the character of the sub-soil by inquiry and inspection of existing excavations, whether additional lands drain upon the area to be drained, the general slope of the lands toward the drains, the character of the outlets, the presence of seepage points from side hills, and the presence of ponds and their probable elevations. This kind of an examination is truly superficial, but nevertheless, when coupled with a working knowledge of tile drain designing for various conditions, together with information gained from the tile line surveys, will enable the engineer more satisfactorily to design the grade lines and point out beneficial corrections in the methods adopted by the owner.

Since this typical owner considers a plat and profile of the survey an unnecessary expense, but must possess some record of the survey for the direction of the workmen doing the work, a list of cuttings should be prepared showing the depths of tile at each 50-ft. station on tangents and each 25-ft. station on curves, and the fall of the grade lines throughout, Fig. 1. To

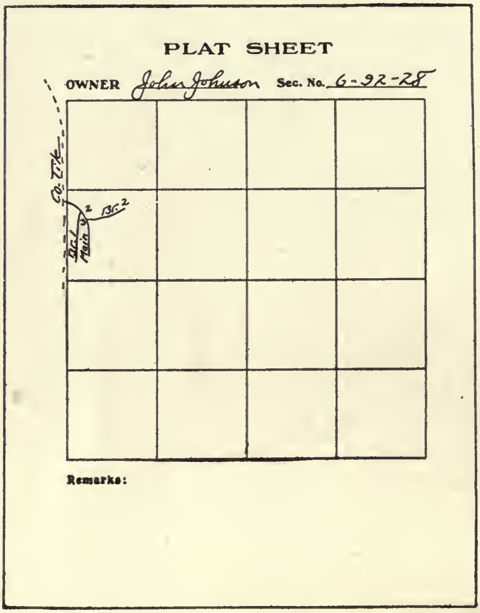
OFFICE OF JOHN DOE, SURVEYOR

Date *June 6, 1912* Survey for *John Johnson* On Section *6-92-28*

	MAIN			BR. NO. 1			BR. NO. 2	
	Station	Depth		Station	Depth		Station	Depth
Fall = 4¼" per 100'	0	3.04'	Fall = 2½" per 100'	0	5.90'	1½"	0	5.72'
	+50	4.12'		+50	5.10'		+50	5.03'
	1	4.24'		1	4.71'		1	4.28'
	+25	5.16'		+25	4.66'	Fall = 3" per 100'	+50	3.88'
	+50	5.33'		+50	4.33'		2	4.24'
	2	6.10'		2	4.20'		+50	5.06'
Fall = 2" per 100'	+50	5.99'		+50	3.98'		3	4.72'
	3	5.88'		3	4.06'		+50	4.31'
	+50	5.71'		+50	4.15'		4	4.00'
	4	5.21'		4	4.00'		+50	4.29'
	+50	4.87'		+50	3.90'		5	4.11'
	5	4.37'		5	4.02'		+50	3.97'
	+50	4.22'					6	4.05'
	6	4.10'						
	+50	4.05'						
	7	4.22'						
	+50	4.00'						

FIG. 1—List of Cuttings for Farm Tile Drain Survey

accompany this list a fairly accurate ink sketch should be prepared, showing the shape of the farm and the locations of the tile lines upon it, Fig. 2. Each tile line may be distinguished upon list and plat by a main, branch or lateral number. These sheets and plats are usually handed to the contracting tiler to be used by him as a guide in the construction of the work, with the inevitable result that at the time of the completion of the work they are worn out or lost, and the owner then possesses not even the simplest record of his improvement. As the present or future owners must certainly many times require some record of the work in cases of repairs, extensions and sales of the land, the engineer should emphasize the importance of preserving a record. This is readily accomplished by the preparation of two copies of the lists and plats by the engineer or their duplication by the owner himself for the use of the tilers. Since the majority of tilers are unable to make use of depths of cuttings stated in feet and decimals, a table of reductions from feet and decimals to feet and inches is convenient for reference until the engineer has become so mentally familiar with their equivalent values that there is little liability of error. (See Table I.) The crude methods of drainage surveying demanded by this class of owners are objectionable to the thorough, scientific engineer, but since it is a fact that a large percentage of land drainage is thus adversely accomplished, it devolves upon engineers to accomplish the best work possible and to raise the standard by a relentless campaign of education.


PLAT SHEET

OWNER John Johnson Sec. No. 6-92-28

Remarks:

Fig. 2—Plat Sheet for Farm Tile Drain Survey

In the second case, the employer has become educated to the economic importance of the engineering design of depths, sizes and distance apart of tile lines, but does not recognize the advantage of proper preliminary surveys to such designing. The preliminary and location surveys must be accomplished in one field operation; therefore the general arrangements of the system and distance apart of the laterals must be determined and executed during the prosecution of the field work. Even closely to approximate the economic design of tile systems under such conditions the engineer must be mentally capable of detecting all natural features and estimating the probable cost and comparative benefits of different possible methods of draining the land. Besides gaining all possible information, as in the first case, elevations of all ponds and ridges to be traversed to outlets should be determined, and the depth and permanence of possible outlets should be especially investigated. These data, which govern necessary depths to furnish satisfactory outlets for laterals, and the possible depths available by the use of the proposed outlet, now become the basis of determining the practicability of the proposed method of drainage and of designing the system in accordance with the general principles of design which will be outlined in a succeeding chapter. The locations of all mains and branches should be tied to known corners and property lines with such accuracy that a suitable plat may be prepared.

In the third case, the accumulation of more accurate and detailed data is permissible in preliminary drainage surveys as the proper basis for intelligent designing. In the prosecution of the survey certain fundamental facts should be determined: (1) the total area of the watershed land delivering overflow or underdrainage water upon the land to be drained; (2) the topography of the watershed; (3) the physical composition of the sub-soils to be drained; (4) the character of the proposed outlet. The location of the boundary line is of particular importance. If land of any extent is excluded from the watershed area that must later drain into the system, the most carefully designed system of tile lines is certain to prove inadequate. A general idea of the watershed area should first be gained by inquiry, and this supplemented by an accurate level survey of the boundary line. This line is readily defined at points where the natural divides are prominent, but in places where these do not exist a number of elevations taken over apparent divides are necessary to ascertain the natural outlets of doubtful ponds, draws and tablelands. At such points little dependence can be placed upon appearance of slopes, as even the most practiced engineers are easily deceived by apparent direction of slopes. Oftentimes areas of considerable extent are found for which there are no distinct natural outlets, but which may be drained to one of two or more outlets. The question of the inclusion or exclusion of such lands must be determined by a comparison of the natural and economic advantages of the respective outlets, the final decision being necessarily largely controlled by the wishes of the land owners concerned. The field record of the boundary line location is made with sufficient accuracy by sketching it upon section sheets and recording the distances of the line from subdivision corners and property lines. The stadia method is especially adapted to the determination of tie distances and the length of watershed lines in certain directions.

Topography by Contours.—The topography of the area to be drained in particular and of adjacent watershed lands in general should next be ascertained. The essential features of topography are most definitely determined by a contour survey of the land. This survey may be rapidly accomplished by locating a line of stakes 200 ft. apart the entire distance around the four sides of the field. A second line is then located parallel with the first and distant 100 or 200 ft. from it. A rodman may then hold the rod on the successive stations across the field on any side line and back on the second line. Stations may be taken 100 or 200 ft. apart as desired by stepping in intermediate stations between stakes. On the third and other interior lines there will be only four stations located by stakes, two at each end of the line. However, the approximate location of any interior station is readily found by sighting to the stakes at the ends of each of the two intersecting lines. The levelman easily distinguishes the location of each station by numbering the lines and sub-numbering or lettering the stations. In case the area contains ponds, the elevations of the stations conflicting with them are found accurately only by gaging the depths of the ponds from the water level. During the prosecution of this survey a number of convenient benchmarks should be established and described for future reference.

Sub-Soil Surveys.—The sub-soil survey of the tract is readily made by the use of the intersecting stations. Test borings are made at each station with a soil auger and a description of the different classes of soils and their respective depths entered in a special soil record book. These borings should extend to a depth of at least 5 ft., and to greater depths where it is evident that deeper excavations will be necessary to secure outlets. Where water-filled ponds are encountered, if possible the soil testing of these areas should be delayed until a dry time or until winter time when ice has formed. If intelligently conducted, a soil survey will determine the texture of the soil, the consequent behavior of percolating water and its direction of flow, which information will prove invaluable to the designer of depths, location, lengths and frequency of tile lines.

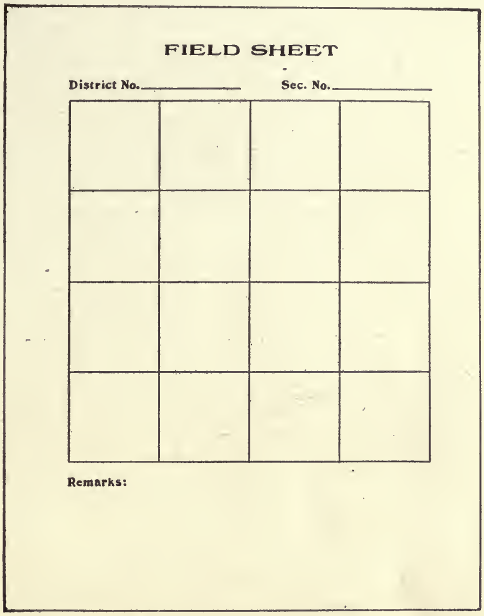
The topography of the adjacent lands of the watershed may be taken in a more general manner by a series of elevations up the draws, in ponds, on the hills and on the slopes with sufficient frequency to approximate comparative elevations and gradients of slopes. The nature and location of topographical features—hills, draws, ponds, marshes, crops and vegetation—may be sketched with reasonable exactness if the area is small, but should be located from traverse lines properly tied in to known points, to which necessary data are referenced, in case larger areas are being investigated.

Outlet Investigations for Private Systems.—As the success or failure of a drainage system, planned immediately for a portion of the watershed area, and eventually for the use of the entire watershed, must largely depend upon the nature of the outlet, certain facts concerning it should be carefully noted: whether the main discharges into a deep, capacious channel or into a steeply sloping draw, or whether into a sluggish, overtaxed channel or a flat draw subject to overflow. The high and low watermarks and the time duration of high water should be found as definitely as may be possible, and the possibility of improving the outlet by extending or deepening should be investigated. A contour plat of the area to be drained and a general topographical map of the adjacent watershed are readily prepared from these data, and, together with other recorded facts of pertinence, become the basis of a proper office design of a tile system.

Consent Drainage Districts.—The drainage engineer is often retained by a number of land owners to survey a watershed and locate outlet drains only, in which cases the general preliminary methods followed in the prosecution of drainage district surveys may be followed. Because of the absence of a central organization and legal compulsion, the tendency of the owners interested in private drains is towards friction and disagreements, a condition which renders it especially important that the engineer be tactful as well as accurate. Such propositions, if involving areas of land of considerable extent, seldom result satisfactorily unless the owners jointly contract in advance that the plans of the engineer selected shall be binding, that proper supervision shall be provided for, and that the division of costs as made by an elected commission or the engineer alone shall be final and binding. Unless such a contract is executed and fulfilled the accomplishment of the work under the state drainage laws is advisable, as more permanent results are assured and the additional cost of a drainage district over the cost of a private district properly planned and executed is negligible unless the particular state drainage laws are unnecessarily cumbersome. One illustration that is typical of many clearly demonstrates the results of private drainage projects which are improperly installed. The engineer was employed and instructed to survey the watershed and draw the plans, and also to set the grade stakes during the preliminary survey work, in order to reduce the incidental expenses. The estimate of cost for the necessary sizes being in excess of that anticipated by the owners, the outlet mains were reduced from an 18 in. to a 14 in. tile and other sizes of proposed tile in proportion, by the owners themselves. Although considerable time had elapsed since the grade stakes were placed, the tile were laid by them, or as many of them as could be located, and no checking of the completed drain was provided for. The work was carelessly executed, with the natural result that the upper portion of the main drain was laid a foot above grade and was so filled with silt as to be practically useless. The costs were divided by the land owners themselves. The principal results were a costly lawsuit between interested owners and the necessity of the later installation of a supplementary drain. The accomplishment of drainage work by private agreements is more desirable in the smaller projects than the larger ones, as the percentage of expense for incorporation into drainage districts is proportionately greater, but in no case should such work be undertaken privately without the execution of binding contracts.

Methods of Conducting Drainage District Surveys.—The organization of extensive areas of land into drainage districts under the drainage laws of a state is essentially for the purpose of securing outlets, hence the preliminary surveys must measure the practicability and economy of outlet systems. The complete preliminary drainage district survey will determine the proper location of all outlet mains and branches, and the extent and topography of the watershed area, with such exactness that a detailed design, plat, profiles, report and specifications and contracts may be executed.

Before engaging in the actual field work of such a survey, the engineer should equip himself with a pad of section sheets properly ruled into forties, with the necessary headings for remarks, and section, township and range numbers. Fig. 3. These sheets are convenient for the field referencing of boundaries, locations and topographical data. Also an office progress plat and profile should be provided, to which field information may be transferred as rapidly as accumulated. Such office records enable the engineer more satisfactorily to study the problems which must be partially or wholly solved before the completion of the preliminary work.



FIELD SHEET

District No.__________ Sec. No.__________

Remarks:

FIG. 3—Field Data Sheet for Drainage Surveys

Location of Watershed Divides.—After obtaining all available information concerning the location, extent and ownership of the lands of the proposed district from county maps and records and government surveys, the initial subdivision of the field work should be the locating of the exterior and interior watershed boundary lines, in accordance with methods previously discussed. Inaccuracies in boundary locations are prolific of future litigation and injustices, as drainage laws governing the later inclusion or exclusion of lands are necessarily cumbersome, and long drawn out, costly legal procedures are often necessary to correct such errors. Much time is conserved in the location of the outer watershed boundary lines by proceeding from the outlet towards the source. This plan precludes the possibility of locating the boundary lines of draws which do not outlet into the proposed district drain. A few attempts to locate from the source towards the outlet will soon demonstrate the dangers of such a procedure. The boundaries of all interior or sub-watersheds should be located with similar precision for convenience in design and assessing of benefits. These interior boundaries should be located even though branch drains are not extended into them as a part of the district system, as capacities of main drains cannot be properly designed without this specific information as to the delivery of watershed water nor benefits fairly apportioned to these subdivisions without these data. This plan of instituting preliminary work serves admirably to acquaint the engineer intimately with his district and its drainage problems, and materially aids him in approximating the portions of the drain which will necessarily be designed as open drain and the portions which may be planned as tile mains, by a perusal of the different sub-areas and their points of discharge into the main drain or its branches. Such knowledge preceding the actual location of the drain is very essential because of the necessity of combining the preliminary and location surveys and the difference in the problems relative to the locations of open and tile drainage.

Outlets—The Objects of Drainage Districts.—The purpose of district organizations, that of securing outlets, must at this time be particularly considered. Petitions for districts are ordinarily only general and not specific as to the number and lengths of mains and sub-main drains, and the decision of these questions devolves upon the engineer. In arriving at conclusions he should be largely influenced by natural features and the wishes and financial readiness of the property owners concerned. Areas of land within the watershed which are found to possess natural outlets into channels, which are reasonably straight and of sufficient depth and capacity according to good designing principles, will require no artificial outlet unless the conditions warrant the substitution of a tile drain. When lands are found to lack natural outlets, without entering upon or crossing lands owned by other parties or which require the construction of a district drain for underdrainage outlets, it is usually advisable to locate the necessary number of branches and laterals to furnish district outlets at the property lines of all such individual farms. This method accomplishes in one legal organization as much as would be possible in many separate ones, at a very distinct gain in the necessary administrative expenses. Another important economic advantage arises from the fact that the opportunity of installing lateral drains is at once offered land owners who otherwise would be compelled to delay the direct drainage necessary to realize on the money invested in the outlet drain which is often a large percentage of or exceeds the cost of lateral drainage. Also because of the dependence of good roads upon underdrainage and the benefits conferred upon the general public by good roads branches may be justifiably located for the purpose of furnishing outlets to or directly draining wet sections of public roads.

It is essential that field locations be practicable and that all data concerning locations be recorded for reference, as the plat, profiles and reports based upon such information become matters of legal record and establishment. Any changes which might be necessary because of faulty preliminary work could be made only by tedious processes of the drainage laws, the result oftentimes being that they are never made.

Location of Open Drains.—In the location of open drains the following general rules and their conflicting requirements should be held in mind: The value of straight courses and gradual curves to stream flow; the desirability of locating drains along property lines wherever possible; the damages to farms of ditches so located as to cut off small inaccessible corners or extending across them in angling, irregular directions; the economy of traversing natural depressions, and the injurious effect of unstable soils upon ditch construction and maintenance. Before commencing the definite location of an open drain the engineer should walk over the entire route of natural drainage, investigating and comparing possible locations and lining out tentative locations with lath or long poles, later locating and measuring the line more accurately. This inspection will often disclose the possibility of draining to different outlets or shortening the line by cut-offs, thus necessitating a number of trial field locations.

Complete records should be kept of the distance of all tangent intersection points from known property lines; the station numbers of the intersection of the lines with all road and property lines, and the general locations of natural watercourses in relation to the proposed drains. Tangent intersections, unfavorably located from property corners and lines, may be referenced by recording the external angles of the tangent intersections and the angle of one of the affected tangents with a property line, the location of the point of intersection of the tangent and property line being fixed by measurements to subdivision corners. The carrying of a line location for long distances by traversing is not sufficiently accurate in fixing the exact location of the lines upon individual farms for mapping purposes, as section and subdivision lines too often are not true to recorded distances and directions. Temporary stakes should be left at intervals of at least 500 ft. to guide the rodman of the level party in locating the lines and stations. Intermediate stations may be closely approximated by the rodman by pacing. The location of tangent intersection points may be marked by heavy stakes or by referencing them to permanent objects.

The later preparation of profiles, true to actual conditions, requires that elevations be determined at each 100 ft. station and at the bottoms of all channels and gullies crossed by the ditch. For convenience during the construction, bench-marks should be located upon permanent objects at about half-mile intervals, the basic bench-mark for the system being established upon the most permanent object available, state or national sea level bench-marks being used wherever they have been established. For the sake of simplicity it is best to assume a datum such that the lowest desired elevation will be approximately 10 ft. The line level data, together with the information to be compiled in the topographical survey of the district and the record of the outlet limitations, furnishes the data upon which to estimate the necessary depths of ditch throughout the course.

Before the completion of the survey, soil borings should in all cases be made at close intervals to the estimated depths of the ditch and a record kept of the soils encountered; whether clay, hardpan, loam, sand, peat, muck, rock, or any combination of them. In case soils are found which will render the construction and maintenance of the ditch precarious, other possible locations and their soils and natural features may be investigated, that the most practicable ditch may be located and designed.

Location of Tile Mains.—The location of tile mains must similarly be based upon natural features and proper designing principles. However, they may be more closely located in the lowest ground, with due regard to straight courses and limiting soil conditions, as tile drains do not injuriously damage lands which are traversed, as do open ditches. The natural formation of many districts permits of a single outlet main or a combination of two or more main outlets, with the respective advantages and disadvantages of each possible plan, all of which should be investigated and considered as affecting the cost and practicability of the entire drainage scheme.

Drainage District Topography.—The object of drainage district topographical surveys is the accumulation of all watershed information which will influence design. Data for contour maps may be and sometimes are compiled, but in the case of individual watersheds of ordinary extent, the author believes this to be an engineering extravagance, of little value in designing, and when mapped to be more confusing to the many persons interested in the project than a simpler map would be. The one thing of greatest importance to correct design and the later division of costs is an accurate record of all watershed elevations. Each sub-watershed should be made an object of special topographical study to determine the elevations and approximate extent of all ponds and depressions, of land subject to intermittent overflow, of the higher lands and the amount and effect of the drainage already accomplished, all of which data may be field located upon the section plats by the necessary ties and measurements. Timber lands wherever they occur should be located and their area determined, especially when they must be traversed by an open or tile drain. Endless trouble has resulted in many cases from the use of mains designed as outlets for submerged lands the depths of water over which were only estimated. No final report should in any case be filed until the exact elevations of the beds of all ponds and depressions have been accurately ascertained and the proper allowances estimated for the shrinkage of peaty and similar soils.

Outlet Investigations for Drainage Districts.—As in the case of the private preliminary surveys discussed, the outlet facilities are important items for investigation. In case there is an apparent lack of an outlet for the proposed district without the dredging of a new channel beyond the proposed outlet, necessitating the organization of a more extensive district than the one contemplated by the petitioners, the engineer should determine and report these facts before burdening the petitioners with the expense of an extensive survey which will be of no immediate value. If the permanence of the outlet is unquestionable or may be made reasonably so by a justifiable expenditure for an extension or the deepening of short reaches of the natural channel, the survey should be executed and records compiled of high and low water stages, time duration of high water, and the probable effect of the improvement upon the lands adjoining the natural watercourse below the outlet point.

To summarize the important items to be considered in the prosecution of a preliminary drainage survey for ordinary drainage conditions, the drainage engineer should accumulate data concerning the topography of the district, the texture of the sub-soils and the character and permanence of outlets, together with all correlated subdivisional information, with engineering accuracy in a form which can be scientifically utilized in the design, construction and maintenance of an economic and practical drainage system.

Table I—Equivalent Values of Inches and Decimals of a Foot

In.	0	1	2	3	4	5	6	7	8	9	10	11
0	.00	.08	.17	.25	.33	.42	.50	.58	.67	.75	.83	.92
⅛	.01	.09	.18	.26	.34	.43	.51	.59	.68	.76	.84	.93
¼	.02	.10	.19	.27	.35	.44	.52	.60	.69	.77	.85	.94
⅜	.03	.11	.20	.28	.36	.45	.53	.61	.70	.78	.86	.95
½	.04	.13	.21	.29	.38	.46	.54	.63	.71	.79	.88	.96
⅝	.05	.14	.22	.30	.39	.47	.55	.64	.72	.80	.89	.97
¾	.06	.15	.23	.31	.40	.48	.56	.65	.73	.81	.90	.98
⅞	.07	.16	.24	.32	.41	.49	.57	.66	.74	.82	.91	.99

CHAPTER II

THE DESIGN OF TILE DRAINS

Factors of Design.—The various factors influencing the design of drainage systems are so dependent upon particular watershed formations and soil compositions that absolute formulas and rules of procedure are impossible of deduction. However, general standards for average conditions may be formulated, and the duty of the drainage engineer is to become familiar with these standards and their value and limitations in relation to each drainage system considered. The design of a tile drainage system, whether a complete farm system or an outlet system for a drainage district, naturally resolves into the following divisions: the location and arrangement of the component tile lines; the depths of tile and adjustment of grade lines; the determination of tile sizes, and the location and design of tile inlets and other accessories. Open drains being necessitated as outlets for tile drains, their design will be discussed after the requirements of the tributary tile systems have been considered. The conscientious engineer, anxious to design an economical and successful system, finds the proper correlation and adjustment of these interdependent details a complex problem demanding true information, trained judgment and comprehensive experience. Hence the attempt will not be made to analyze each consecutive division of the subject for rule of thumb application to certain conditions, but to suggest necessary lines of investigation for the accomplishment of efficient design.

Location of Farm Drainage Systems.—The location principles for drainage district mains having been discussed in Chapter I, the proper distribution of mains and laterals for farm systems remains for consideration. However, many of the important facts affecting the location of farm drains are also applicable to drainage district mains. Assuming a satisfactory outlet, the governing points are: the shape of the tract, the surface slope of the land, and the physical structure of the soil. If the area to be drained is comparatively level, all of which requires drainage, the main or mains should be located in the course of the lowest depressions as nearly as possible and still be reasonably straight and in such a location that radiating laterals may be extended at right angles to contour lines, of minimum number and of maximum safe lengths.

Length and Arrangement of Laterals.—A system of long laterals is desirable, as each junction of lateral and main results in the installation of portions of the lateral through land already sufficiently drained by the main. When additional depths are necessary to secure laterals of desired lengths, a system of shorter laterals may prove more economical and effective. Because of friction in long laterals of small size and the tendency of small tile to collect silt and become obstructed, it is best to limit the lengths of low grade laterals to approximately 1,000 ft. Greater lengths of small laterals should be avoided where possible, as it is usually cheaper to plan a different arrangement than to increase the expenditure per unit of length for the larger tile that would be necessary for the outlet portions of the laterals.

The tract may be of such shape and slope that one main and a system of laterals radiating from each side will successfully drain it, the low swale may be along one edge so as to require one or more laterals paralleling the main on one side and a system of laterals located about at right angles to the main on the opposite side, or on account of the irregular shape and contour two or more mains with accompanying systems of sub-mains and laterals may be advisable.

The direction of surface slope as determined from contours or surface elevations and the composition of the soil are the determining factors in fixing the distance apart and location of the laterals. The arrangement should be so adapted as particularly to relieve the denser soils, which are least affected by natural drainage, if the soil is variable, but may be more regular as to direction and distance apart if the soil is uniform. For tracts of slight slope which are to be thoroughly drained, the direction and arrangement of laterals are governed largely by the shape and area and the limits of safe lengths, but in all cases the laterals should extend in the direction of sub-soil flow—practically at right angles to contour lines—especially in cases of the more pronounced surface slopes. Proper distances apart of laterals to accomplish efficient drainage are difficult to tabulate, as soils varying from the extreme of fine to the extreme of coarse particles require spacing varying from 25 to 400 ft. apart. To determine this distance, the engineer should carefully analyze the soil for density in each particular case and investigate similar existing systems as far as possible and also all available published accounts of tile systems constructed in similar soils. The results of drainage systems designed upon the basis of such data may not be satisfactory in all cases, but they are certain to be much more efficient and economical than an arbitrary distance adopted for all systems could accomplish. The effect of a standard distance apart for all soil conditions must be either incomplete drainage or unnecessary expense in almost every case, thus the necessity and importance of educating the land-owning public and drainage engineers in the physical characteristics of soils in relation to drainage.

Arrangement of Tile Lines for Undulating Land.—The arrangement of tile lines for the drainage of undulating lands consisting of hills, draws and ponds is necessarily random. Three important rules should be observed in the drainage of draws: Locate all laterals very closely in the direction of sub-soil drainage; extend laterals a sufficient distance to extend through all seepage points on side hills to the more porous soils above, and apportion the distance apart of laterals according to the porosity of the soil. The different parts of the system may readily be assembled in the process of meeting these requirements. A narrow draw of sufficient gradient in its lengthwise direction to counteract the tendency of soil water to flow transversely through the joints of the tile toward the center of the draw is best drained by two or more laterals extending in the direction of the greatest length of the draw, the two outer ones being located near the bases of the side hill slopes. However, draws are generally irregular in width, contain a number of small ponds and depressions, and are intersected by a number of natural drainage courses requiring tile, and consequently are most effectively drained by the location of the main as near the center of the draw as straight courses and gradual curves will allow, a system of sub-mains and laterals being extended where necessary. In this case and all others the too common practice of effecting changes of direction by abrupt angles instead of apportioning the change among several 25 ft. stations should be avoided, as the tendency of the suspended matter to deposit is encouraged because of increased friction and decreased velocity, resulting in loss of capacity and sometimes complete stoppages of the tile lines. Figure 4 and Fig. 5 are views of the two methods practiced in making the tile ditch curves.

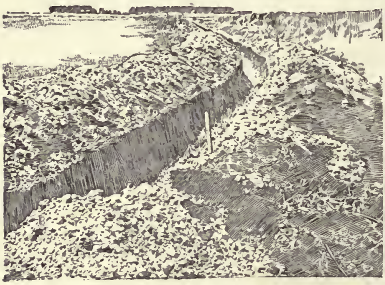


FIG. 4—View of Tile Ditch Curve—The Right Way

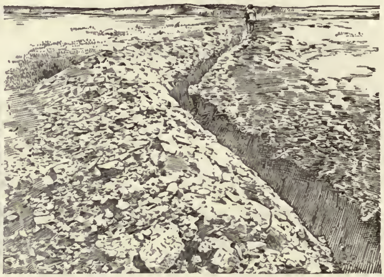


FIG. 5—View of Tile Ditch Curve—The Wrong Way

Arrangement of Tile Lines for Depressions.—Small depressions are usually drained by being intersected by the system of laterals necessary for the drainage of the tract, but oftentimes ponds or depressions of considerable area are found which are joined for the greater portion of the distance around them by steep lands requiring little drainage and marked by seepage lines at the bases of the slopes, in which cases special treatment is necessary. In these cases the sub-soil drainage from the side lands is intercepted and forced to the surface (in the form of seepage) by underground ridges of dense soils. This seepage water is readily collected by locating tile lines around the outside edges of the pond in the more porous soils above the line of seepage. As such intercepting tile lines are necessarily located without regard to their distance apart, a system of (interior) laterals arranged according to the shape of the pond and density of the soils should be planned, an inlet being provided to permit the rapid entrance of surface water into the collecting main.

Arrangement of Tile Lines for Seepage-Affected Land.—The presence of seepage lines as determined by sub-soil borings and surface appearances should in all cases influence the location of tile lines, as otherwise perfect natural underdrainage is often impeded by sub-soil ridges of clay or other impervious soil. A failure to acquire and apply this specific information results in an incomplete drainage system, particularly where these ridges occur on the slopes of steep side lands which in comparison with adjoining lands are apparently self-draining, but which prove to be boggy and untillable during wet seasons. Considerable areas of lands of this character may often be furnished complete drainage by the installation of a single line of tile penetrating through the impervious ridge into the basin. Springy points result in particular damage to steeply sloping hillsides, as the underground water, when forced to the surface, tends to erode the soil and form side-hill gullies and ditches. Experience has proven that tiling will effectually prevent such erosion and maintain the surface of the slope below the seepage point in a tillable condition.

Comparison of Tile Routes.—Often the necessity arises of comparing the advantages of two different routes for a tile line, especially where it is possible to shorten the length and reduce the cost by extending the location across a ridge instead of by way of the natural watercourse. Watersheds of considerable area may sometimes be economically diverted, or minor changes advantageously made in obviously natural locations, if the course of natural drainage is followed. However, natural watercourses should in general be closely approached in the location of tile lines, as direct drainage results throughout the entire length of the line, the necessary depths of excavation are usually less, and the consequent cost of installation and danger of encountering treacherous soils are minimized. In considering a change of location, two resulting disadvantages should be duly considered: the necessity of installing a tile main at some time in the abandoned watercourse of sufficient capacity to drain the tributary lands and in addition care for the overflow waters which are inevitably discharged over the lower lands from the lands above the point of cut-off, and the probable excess cost of installation and maintenance of the cut-off line because of sand strata or other unusual conditions encountered. On the contrary, the cut-off line furnishes direct drainage and outlets to the lands adjacent to it, and the saving in first cost may be considerable. Favorable conditions might result in a very marked saving in the last item, while unfavorable conditions might result in a greater first cost for the cut-off line. This process of loss and gain computation simply consists in balancing the gain in first cost plus the value of direct resulting drainage of the cut-off line against the loss of direct drainage in the natural watercourse and the greater maintenance cost of the cut-off line. Unless the possible changed location, if of any importance, is very materially justifiable, it is best to adhere to the natural watercourse, as criticism and litigation often result because of the tendency of property owners to suspicion such deviations.

Depths of Tile and Arrangement of Grade Lines.—The proper depths of tile and arrangement of grade lines is directly dependent upon the character of the soil and comparative surface elevations and gradients. The following facts bearing upon depths will not be analyzed, as they are generally accepted as truisms by engineers and largely so by land owners, due to the activities of State Experiment Stations and the United States Office of Drainage Investigations: (1) the object of land drainage is to lower the ground water table to a plane just below the depth to which local crops will penetrate for food and moisture; (2) the movement of soil water toward tile lines is generally downward between lines to the plane of saturation and thence in a downward curving direction to the tile lines, where it enters the tile through the lower portions of the joints; (3) the height of the plane of saturation is governed by the density of the soil and the distance apart of the tile lines, this plane being theoretically coincident with the bottoms of the tile lines if the soil is thoroughly drained; and (4) tile drainage does not remove the capillary water from the soil, but only the excess hydrostatic water, which injures growing crops. Since the soil never becomes thoroughly drained during wet seasons because of the resistance of the soil particles, excessive rains and limited capacity of the tile lines, the average depth of drainage accomplished will be considered as extending to the level of the tops of the laterals on the assumption that thorough tile systems will lower the water table between lines to this level before serious injury to crops results.

Minimum Depths of Tile Lines.—The minimum depth of tile lines must be varied to compensate for soil conditions. If an analysis of the soil shows the surface to consist of fine particles and the sub-soil to be gravelly or sandy, which will be self-draining, it is unnecessary to extend the tile into the sub-soil farther than required to collect the soil waters in the loose-grained strata; but if the reverse condition is true, it is advisable to fix the minimum depth of tile laterals at approximately 4 ft. This is at variance with the theory that tile should be placed above the more impervious strata to insure rapid drainage, but as this finely divided soil contains valuable plant food, it is better economy to plan a system which will render this food available to plant roots at all times and provide for rapid drainage by a closer spacing of lines, surface overflows and tile inlets. The same line of reasoning would apply to soils consisting of fine grains for the entire desired depth of drainage as regards the availability of plant food. Systems of tile lines placed in close-grained sub-soils which are overlaid with looser soils may be relieved by the placing of lines of tile at shallower depths at occasional intervals. This method serves the double purpose of draining and aerating the sub-soils and rapidly removing soil water from the looser soils above.

Adjustment of Gradients.—In the process of fixing the grade line upon the profile certain points are arbitrarily established for any tile line which serves as a collector for laterals by the outlet requirements of the low points and the limitations of the available outlet. From the comparative elevation data and the field survey notes the necessary depths of laterals in the lowest depressions and the minimum fall permissible for their required lengths may be computed and the necessary elevations to furnish outlets noted on the junction points on the profile sheet. These elevations and the adopted elevation of the grade line at the outlet form the limits of the possible adjustment of the intermediate portions of the grade line. While a minimum fall of 2 in. per 100 ft. is advisable for laterals and 1 in. for larger mains, such a standard cannot be strictly adhered to, as outlet limitations often necessitate flatter grades and shallower depths than desired, in which cases larger sizes of tile and a closer spacing of the tile lines in the low spots should be designed. Where small, deep ponds are intercepted by laterals it is better to sacrifice depth in the lower portions of the pond in order to permit a greater fall to grade line. But if the area in the bed of the pond or slough is of sufficient extent to require the placing of branch tile lines to complete its drainage, fall should be sacrificed to depth, as such spots become the most fertile portions of a farm when drained and subdued, and any economy which will reduce its capacity for production is unjustifiable.

In general it is desirable to connect laterals to mains in such a way that the tops of the two intersecting lines will be about on the same level, but if the outlet conditions require, they may be joined at lower points, but always should be high enough to allow the use of special junction tile for connection purposes. The necessary elevation of the grade line of the lateral to fulfill this condition may be determined for any given case by adding one-half the diameter of the main tile from outside to outside to the elevation of the grade line of the main at that point and then subtracting one-half the diameter of the connecting Y from outside to outside. After the determination of the foregoing points for any given case, the grade line may be determined throughout the entire course of the main. As far as possible, the principle of laying the tile above sand strata should be observed by changing the rate of fall at controlling points. The outlet requirements for points of low elevation and the limitations of outlet may necessitate a slight uniform grade throughout, in which case no variations are possible to evade the penetration of treacherous soils. In the more substantial soils deeper excavation, steeper grades and smaller tile are preferable to shallower depths, flatter grades and larger tile, unless material saving of expense is possible by the use of the latter plan.

The fixing of the grade line elevation at the outlet of a tile line is dependent upon the requirements of the subsidiary tile system and the character of the channel or swale into which it empties. Favorable conditions for the satisfactory arrangement of grades are comparatively high elevations of the land to be drained and deep, capacious outlet channels. But in the average locality requiring extensive drainage such ideal conditions rarely exist for the larger outlet mains. In all cases possible the grade line should be above the outlet high-water mark, although good drainage is sometimes effected by making it on a level with the base of the outlet channel, especially if the capacity of this channel as governed by size and gradient is sufficient to carry away all waters received as rapidly as they are discharged into it. Tile outlets submerged below the level of the channel base, although fairly satisfactory if properly protected and maintained, and if the tile line possesses sufficient head to raise the level of discharge at the outlet considerably above the level of desired drainage for the low lands, are as a rule to be avoided for purposes of permanent satisfactory drainage.

Protection from Roots.—The most permanent method of protecting tile lines from the penetration of tree roots is the destruction of the trees. Tile lines may be located within approximately 25 ft. of fruit and similar trees whose roots do not ramify extensively without being seriously affected. The roots of willow and similar trees extend for great distances through the soil in search of moisture and unless tile joints are effectively closed they will completely obstruct tile drains in a short space of time. To be exempt from such roots tile lines should be located at least 100 ft. distant from the trees. If it is undesirable for any reason to remove the trees or locate the tile line at this distance from them, the joints should be protected. The joints of drain tile may be surrounded with a ring of cement mortar, but this plan is open to the objections that large quantities of mortar are necessary to form permanent rings, in the case of clay tile that cement mortar does not readily adhere to clay tile, and that any uneven settling of the tile tends to break the mortar joints. These disadvantages are largely overcome by the use of sewer pipe and cementing the joints.

Effect of Run-Off upon Tile Sizes.—The sizes of tile should theoretically be designed to remove sub-soil and surface overflow waters with such rapidity that crops will not suffer injury. While records of rainfall are useful aids in estimating the amount of water to be removed, the rate of removal necessary is so varied by watershed topography and soil composition that exact tile size formulas based upon rainfall cannot be evolved. Also since the cost of tile installation is greatly increased by small increases in the sizes of tile it is questionable economy to design tile lines of sufficient sizes to completely protect farm lands from excessive rains which occur only at intervals of several years. For the smaller watersheds and average soils tile systems designed to remove ¼ in. depth of water from the entire shed in twenty-four hours, from experiments and experience, have been found generally satisfactory. The total average amount of run-off from such watersheds has been computed by government and other competent engineers to be approximately ½ in. depth or more in the same time, but as a portion is delivered over the surface, and as a tile system operating continuously rapidly renews the reservoir capacity of the soil, thus regulating the removal of excess water over longer periods of time, the ¼ in. standard has proven reasonably satisfactory. This rate of removal can be adopted only as an average of extreme rates and must be varied from ⅛ to about ¾ in. to compensate for various conditions which tend to increase or decrease the average rate. Some of these influencing conditions and their general effect upon the rate of removal will be discussed.

Relation of Topography to Run-Off and Tile Sizes.—The rapidity with which under and surface drainage water is delivered to main tile lines is governed by the gradient of the watershed slopes and the porosity of the soils. Surface water is delivered from the steeper slopes in larger quantities in the same time if the soil is impervious than when it is more sandy and porous. In the latter case the rainfall is more readily diverted to the soil and passes through the lateral tile lines or sub-drainage courses more slowly because of the resistance of the soil particles. The more level side lands of rates of gradients ranging from 5 to 15 ft. per mile tend to retain the flood water upon the surface of crop lands and in depressions, thus allowing it to be collected and delivered over longer periods of time by lateral tile lines and permitting the designing of less capacity for the main. In this connection all tile lines which serve as collectors for other tile lines are referred to as mains. After estimating about the rate of delivery of water to the main draw it is next in order to ascertain the proportion of the surface water discharged into the draw that will naturally drain off over the surface. If the main draw has a steep, fairly regular surface gradient, a portion of the surface waters spreads out and escapes over the surface. The very flat draws do not allow material run-off in this way. If in either case deep ponds or depressions occur along the draw at regular intervals, which serve as catch-basins for surface water, little allowance can be made for surface removal unless overflow ditches are constructed of sufficient depth and capacity to remove this collected water.

Value of Overflow Ditches.—Overflow ditches are valuable adjuncts to tile lines if properly maintained, and often allow of a very material reduction of size, but as they usually serve a number of land owners and also are generally under the supervision of public drainage authorities, there is a grave tendency for such ditches to gradually fill because of individuals farming through them. Close inspection being lacking, such conditions are allowed to become aggravated, and serious losses result before the interested property owners become aroused, condemn all persons connected with the design and construction of the system, and spend a repair sum closely approaching the original cost of the overflow. While great relief is possible to individual farms by the respective owners maintaining shallow overflow ditches, they are not practicable for drainage organizations unless some system can be devised for annual maintenance, in which case the original and maintenance cost of an exclusively tile line, a tile main and overflow combination, and an open ditch, should be carefully estimated and compared. When it is considered that overflows closely approach the widths of open ditches and that the overflows should be fenced and bridged to insure permanence, the advantage of a tile main and overflow over an exclusively open ditch is not so apparent, especially as the cost of the overflow and tile is largely in excess of the cost of the open drain.

Minimum and Maximum Sizes of Tile.—The minimum and maximum sizes of tile to be used for drainage systems are questions which must be determined by land values and other local conditions. Although 3 and 4 in. tile are used with apparent success in very porous soils, the use of these sizes is being discontinued in many localities to such an extent that local tile yards have ceased to keep them in stock. Because of the small variation of grade certain to occur in even the best laid tile lines and the tendency of soil particles to enter the tile with soil water and become deposited and clog the line, the minimum sizes for permanent systems should be in most cases 5 in. tile. The determination of maximum sizes involves such large items of cost that arbitrary limits are not readily determined. While certain influences may tend to permit the adoption of a comparatively less depth standard of removal for larger areas than for smaller ones, the difficulty of providing means of escape for surface waters with sufficient rapidity as is possible by the use of open drains probably completely counterbalances this advantage. Hence such large sizes of tile and consequent prohibitive costs are necessary for total watershed areas greater than 1,200 to 2,000 acres that sizes of tile larger than 24 to 28 in. in diameter are seldom economical.

Effect of Underground Watercourses upon Tile Sizes.—Conditions are sometimes encountered by drainage engineers for which sizes of tile designed according to good drainage practice for ordinary soils would be an economic waste. In some localities natural sink wells extending to crevices in underlying rock strata are common, which will completely or partially drain all lands tributary to them. In case they will remove only part of the soil waters, tile drains are necessary, but their sizes should be designed only of sufficient capacity to care for the estimated excess water, allowing a liberal margin as a factor of safety if there is any doubt as to the reliability of the sink well. These underground watercourses sometimes also exist as porous strata of soil extending in a horizontal direction to some springy outlet and they furnish complete or partially complete drainage to the areas involved. In such cases comparatively small sizes of main tile may relieve areas of land for which sizes of tile of several times their capacity would ordinarily be necessary. Each project of this nature must be investigated separately for such unusual factors and their value computed by all information available.

Tile Size Formulas.—There are a number of formulas extant for computing sizes of tile for given depths of removal in a given time. Poncelet's formula, which perhaps has been the most popular, is as follows:

$$Q = 48\,A\sqrt{\frac{D \times F}{L + 54D}}$$

in which Q = Discharge in cubic feet per second.
A = Area of tile in feet.
D = Diameter of tile in feet.
F = Total fall of drain in feet.
L = Length of drain in feet.

The number of acres drained is found by dividing the discharge by a constant representing the number of cubic feet per second necessary to relieve one acre of a given depth in 24 hours. The constants most used are:

0.0052 cu. ft. = ⅛ in. per acre in twenty-four hours
0.0105 " " = ¼ " " " " " "
0.0140 " " = ⅓ " " " " " "
0.0210 " " = ½ " " " " " "
0.0315 " " = ¾ " " " " " "
0.0420 " " = 1 " " " " " "

In using the formula, the number of acres in the watershed multiplied by the assumed constant may be substituted for Q, and the formula solved for the diameter of the tile. Because of the resulting loss of head from friction in long drains, allowances in size for extremely long drains of the same size throughout and on flat grades should be made, although increases in size are usually required at short intervals in main drains because of additional water to be carried. The friction head thus being reduced in the larger tile renders this item of less importance. Allowances may be made in this formula for additional pressure head resulting from steep gradients of side laterals by adding to the fall of the main drain the average mean value of the additional heads of all main laterals above the elevation of the upper end of the drain, but because of the variable character of watershed soils and topography it is probably best to use the actual head of the main in the calculations, all other conditions affecting the collection and removal of soil water being considered in fixing a depth of removal.

Since the Chezy-Kutter formula is so generally used in hydraulic experiments and calculations, it is probable that this formula will become more widely used by drainage engineers. The Chezy formula is as follows:

$$V = c\sqrt{rs}$$

in which V = Velocity in feet per second.
c = A coefficient found by Kutter's formula.
r = The hydraulic mean radius.
s = Slope or fall in feet divided by length in feet.

The simplified Kutter's formula is as follows:

$$c = \frac{41.6 + \frac{1.811}{n}}{1 + \left(\frac{41.6\ n}{\sqrt{r}}\right)}$$

and the values of n which are applicable to drainage systems, as taken from Trautwine's Pocketbook, are:

Glazed pipes and very smooth iron	0.010
Iron pipes	0.012
Ashlar or brickwork	0.013
Canals in firm gravel	0.020
Canals having stones and weeds occasionally	0.030
Canals in bad order	0.035

In this Kutter's formula the value of n for tile drains is generally accepted at approximately 0.013, and based upon this coefficient and a grade of 1 in 100, Table II, rearranged from the Twenty-fourth Annual Report of the Illinois Society of Engineers and Surveyors, is deduced from this formula and greatly facilitates its use. The velocity and discharge of a tile on any proposed grade is determined by multiplying the velocity and discharge opposite the given size in Table II by the square root of the proposed grade taken from Table III. For convenient reference, sizes of tile based on this formula on the basis of ¼ in. removal in 24 hours are here given, Table IV. In case it is desired to compute the acreage value for other depths of removal than ¼ in. for given tile sizes the number of acres given in the table may be increased or decreased in an inverse proportion to the depth of removal. For instance, to determine the acreage value of a given size for a removal of ⅛ in. depth in 24 hours, the tabular number of acres should be multiplied by 2. In all such cases the tabular value should be multiplied by the quotient of ¼ or .25 in. divided by the desired depth of removal.

Summary.—In this discussion concerning the principal requirements in the design of tile drainage systems, special emphasis has not been placed upon the location and arrangement of the component tile lines, the fixing of the grade line or the determination of tile sizes, but all have been considered as of particular importance. The design of a system must be in accordance with all of these principles properly correlated if the successful operation of the system is to be insured.

Table II—Velocity and Discharge of Circular Conduits Based on Kutter's Formula. $n = .013$ Grade = 1 in 100 or $s = .01$

Diam. of Conduit in Inches	Velocity, Feet per Second	Discharge, Cubic Ft. per Second	Diam. of Conduit in Inches	Velocity, Feet per Second	Discharge, Cubic Ft. per Second
4	1.81	0.16	24	7.24	22.74
6	2.52	0.49	26	7.67	28.27
8	3.17	1.11	28	8.08	34.53
10	3.77	2.05	30	8.48	41.64
12	4.34	3.40	32	8.88	49.59
14	4.90	5.24	34	9.26	58.36
16	5.39	7.49	36	9.63	68.09
18	5.87	10.37	38	10.00	78.78
20	6.35	13.85	40	10.36	90.39
22	6.80	17.94			

Table III—Grades Per Cent and Their Square Roots

Grade per 100-ft.	Sq. Rt. of Grades	Grade per 100-ft.	Sq. Rt. of Grades	Grade per 100-ft.	Sq. Rt. of Grades
.04	.200	.30	.548	1.40	1.183
.05	.224	.35	.592	1.45	1.204
.06	.245	.40	.632	1.50	1.224
.07	.265	.45	.671	1.55	1.245
.08	.283	.50	.707	1.60	1.265
.09	.300	.55	.742	1.65	1.285
.10	.316	.60	.775	1.70	1.304
.11	.332	.65	.806	1.75	1.323
.12	.346	.70	.837	1.80	1.342
.13	.361	.75	.866	1.85	1.360
.14	.374	.80	.894	1.90	1.378
.15	.387	.85	.922	1.95	1.396
.16	.400	.90	.949	2.00	1.414
.17	.412	.95	.975	2.05	1.432
.18	.424	1.00	1.000	2.10	1.449
.19	.436	1.05	1.025	2.15	1.466
.20	.447	1.10	1.049	2.20	1.483
.22	.469	1.15	1.072	2.25	1.500
.24	.490	1.20	1.095	2.30	1.517
.26	.510	1.25	1.118	2.35	1.533
.28	.529	1.30	1.140	2.40	1.549
		1.35	1.162		

TABLE IV—NUMBER OF ACRES DRAINED OF ¼ INCH IN 24 HOURS.

Size Grade	.04	.06	.08	.10	.12	.14	.16	.18	.20	.25	.30	.40	.50	.60	.70	.80	.90	1.00
4"	3	4	4	5	5	6	6	6	7	8	9	10	11	12	13	14	14	15
6"	9	11	13	15	16	17	19	20	21	23	26	29	33	36	39	42	44	47
8"	21	26	30	33	37	40	42	45	47	53	58	67	75	82	88	94	100	106
10"	39	48	55	62	68	73	78	83	87	97	107	123	138	152	163	174	185	196
12"	65	79	92	102	112	121	129	137	145	162	178	205	229	250	271	289	307	324
14"	99	122	141	158	173	187	199	212	223	250	273	316	353	387	418	446	473	499
16"	143	174	202	225	247	267	285	302	318	357	391	450	503	552	597	638	676	713
18"	197	242	280	312	342	369	395	419	441	494	541	624	698	765	827	883	937	988
20"	264	322	373	417	456	493	528	559	590	660	723	834	933	1022	1104	1179	1251	1319
22"	341	419	484	540	591	639	683	724	764	854	936	1080	1208	1324	1430	1527	1621	1709
24"	433	531	613	684	749	810	866	918	968	1084	1187	1369	1531	1678	1813	1935	2054	2166
28"	658	806	931	1039	1138	1230	1315	1394	1470	1644	1802	2078	2325	2549	2753	2940	3121	3289
32"	945	1157	1337	1492	1634	1766	1889	2003	2111	2361	2588	2985	3339	3660	3953	4222	4482	4723
36"	1297	1579	1835	2049	2243	2425	2594	2749	2899	3242	3576	4098	4585	5026	5428	5797	6154	6485
40"	1722	2109	2436	2720	2979	3219	3441	3650	3848	4304	4717	5441	6086	6672	7205	7695	8170	8609

CHAPTER III

TILE DRAIN OUTLET WALLS AND INLETS

Importance of Tile Drain Accessories.—In addition to the accurate planning of the details of location, depths and sizes of a tile system, the necessary accessories, such as outlet retaining walls and storm-water inlets, should be as thoroughly designed. Tile systems designed and constructed in accordance with proper principles in all other details are subject to serious failure at critical times if these important items are entirely neglected or faultily designed.

Location and Design of Outlet Walls.—The design of an outlet protection for a tile main is governed by the location of the outlet portion of the tile line with reference to the natural watercourse, the elevation of the outlet channel as compared with the elevation of the base of the tile outlet, and the nature of the soil at the outlet. For all tile outlets, whether consisting of a natural draw or channel or an open ditch, it is preferable to locate the outlet portion of the tile line to one side of the natural overflow watercourse as far as topographical limits and straight courses will permit, because of the dangerous tendency of overflow waters to wash channels through the looser soils over the tile line, cut their way around the retaining wall and eventually undermine the wall, expose portions of the tile line and wash the wall, tile and large quantities of earth into the outlet channel.

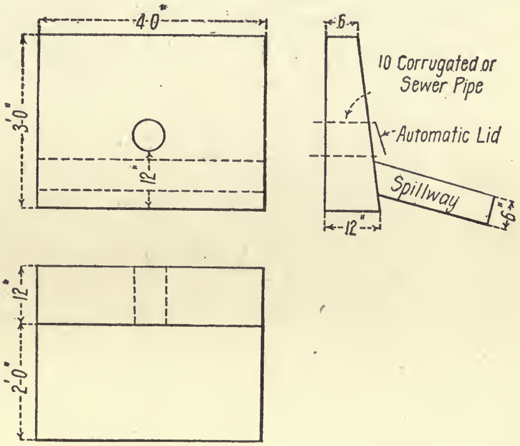


FIG. 6—Design of Outlet Wall for Tile Drains Under 12 Inches in Diameter

In cases where open ditches serve as outlets, combination flood water and tile outlets may be constructed, so designed as to receive the overflow waters into the tile line at a point near the outside edge of the waste bank. This plan necessitates the location of the tile lines in the lowest points near the ditch and the collection and discharge of all tile and flood waters from each sub-watershed at one point, thus resulting in the maximum pressure against the joints of the tile and retaining walls and the consequent necessary installation of complicated and expensive outlet protections. Because of these objections it usually proves more satisfactory to locate the outlets of all tile lines in the higher ground to one side of the natural watercourses and design separate outlets for the flood waters through the waste banks in the low points. This method allows the design of simpler tile outlet walls and will insure the tile for all practical purposes permanently against washouts. Then only flood waters remain to be carried through the waste banks and less expensive ditch inlets may be constructed and maintained for this purpose.

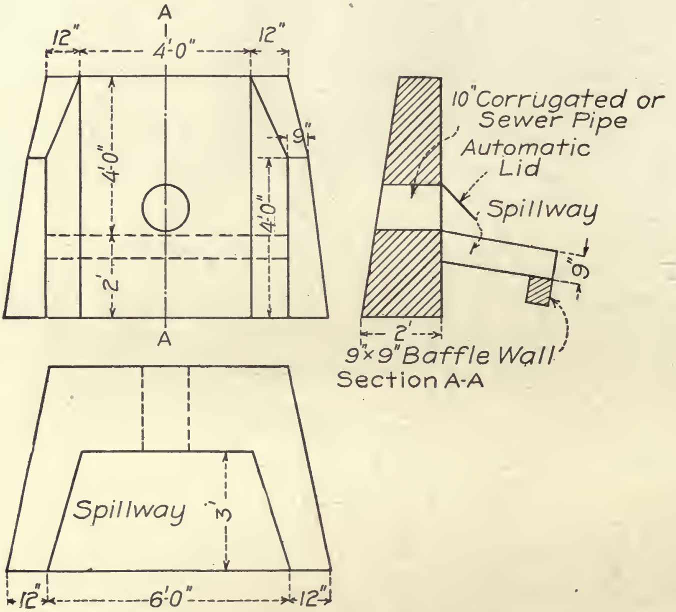


FIG. 7—Design of Outlet Wall for Tile Drains Over 12 Inches in Diameter

All tile outlets should be protected by means of corrugated steel pipes or cemented sewer pipe to prevent the water confined in the tile line from forcing through the joints, displacing the soil surrounding the tile and gradually scouring the surrounding soil into the outlet channel. This tendency is greatly exaggerated if surface waters are allowed to pass over the tile line, therefore the less surface water that must be contended with and the more substantial the soil at the outlet the less becomes the necessity of massive retaining walls.

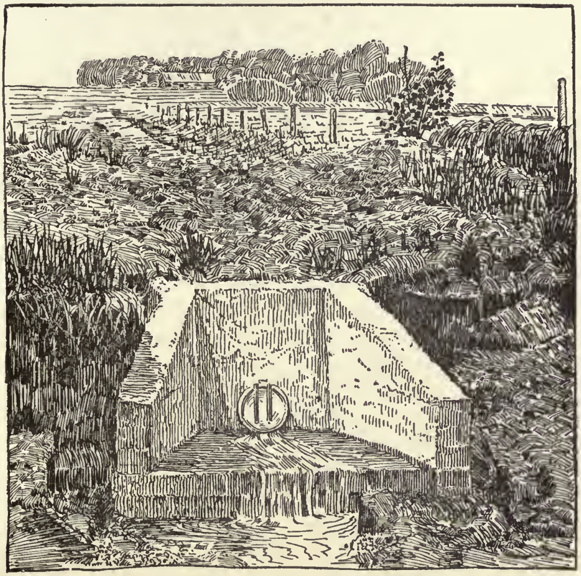


Fig. 8—View of Wing Retaining Wall

For smaller sizes of tile and average conditions, corrugated steel pipes secured by heavy stakes or walls, constructed according to retaining wall design, Fig. 6, are satisfactory. For sizes ranging from 12 in. to the largest sizes in use, wing walls insure greater permanency, as indicated by retaining wall design, Fig. 7. Figure 8 is a view of this type of wall. When the topographical formation renders it necessary to place the outlet in a natural watercourse, straight walls similar to retaining wall design, Fig. 6 (view of wall, Fig. 9), built well into the banks on each side of the channel, and of proportionately greater dimensions, are best. In the last case overflow waters may be allowed to pass over the wall, the top being curved downward slightly from the outsides to the center to facilitate the collection and discharge of surface waters, or they may be diverted to the tile line through an inlet, it being usually advisable to allow it to pass over the wall to obviate the tendency of the soil around the inlet to become displaced and endanger the entire wall. The removal of tile and overflow waters through the waste banks at the same points may be effected by planning an inlet in accordance with inlet design, Fig. 10, over the line back of the waste bank, providing for a retaining wall similar to retaining wall design, Fig. 7, and replacing the portion of the tile line between the inlet and retaining wall with corrugated steel pipe or thoroughly cemented sewer pipe, the size being proportionately greater to provide capacity for the combined tile and overflow discharge. Because of the churning action of the water in front of outlet walls and its resulting tendency to undermine the wall, all outlet protections should be provided with floors or spillways for the discharge water to flow over.

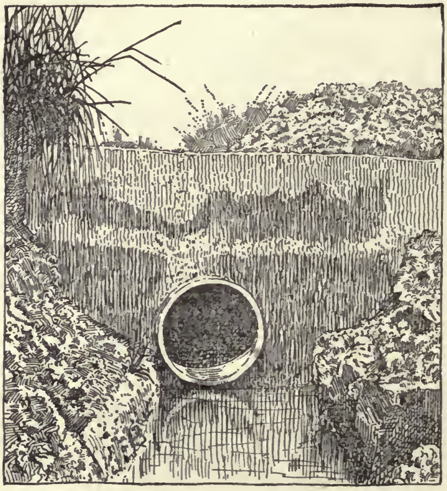


Fig. 9—View of Straight Retaining Wall

These outlet designs are necessarily those applicable to average conditions, and variations are necessary to provide for unusual requirements. The distance between wings, the slope and shape of the spillway, and the depth of foundations, are the most variable parts of retaining walls, although the thickness of walls and wings should be increased for the larger walls. For tile outlets greater than 24 in. in diameter, the distance between the wall ends of wings should be proportionately increased to provide stability and space for the flow water to discharge. The angle of wing walls with main walls, length of wings, and distance apart of extreme ends of wing walls may be arranged in any combination required to support the earth filling and spillway and deflect the direction of flow into the outlet channel, the distance between the extreme ends of wings being in all cases fixed greater than the distance between the inner ends. If the elevation of the outlet tile is at a considerable elevation above the outlet channel, it is best to give the spillway a greater slope and construct a cut-off wall extending downward below the outer end of the spillway, thus insuring more rapid and regular flow discharge and preventing the undermining of the spillway. The foundations should extend at least 2 ft. below the top of the spillway to insure stability unless the spillway is greatly sloped, in which cases the depth of the foundation may be safely fixed at approximately 6 in. below the base of the spillway at its outer end, and the base of the foundation of the main wall and wings be continued on the same level plane. The nature of the soil should also influence the depth of foundations, as unequal settlements and cracks are certain to occur if the supporting soil is unstable. If stable soils cannot be reached by reasonable excavation, all precautions should be taken that are practicable, as the reinforcement of the wall, the depositing of masses of stone, tile bats or piles below the foundation, and similar measures.

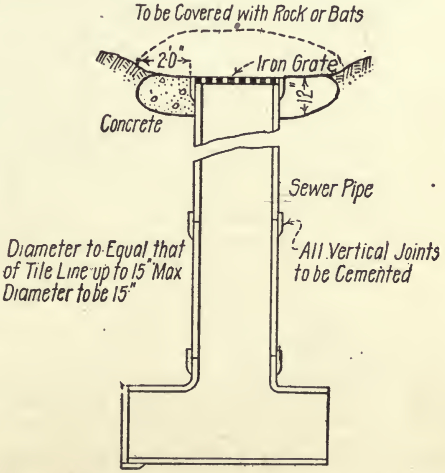

To be Covered with Rock or Bats
2'0"
Iron Grate
12"
Concrete
Sewer Pipe
Diameter to Equal that of Tile Line up to 15" Max Diameter to be 15"
All Vertical Joints to be Cemented

FIG. 10—Design for Inlet Directly Over Tile Line

Design of Tile Inlets.—The advisability of providing tile lines with inlets as an aid in the rapid removal of surface waters is open to question because of the serious tendency of such inlets to become clogged with rubbish, to carry silt into the tile lines and sometimes to become the receptacles of stones and rubbish thrown into them by thoughtless persons. However, if they are designed and constructed properly, placed in the lowest points, and every precaution taken to prevent failure, they prove valuable adjuncts to tile lines. The capacity of pipe placed vertically being largely in excess of that of pipe placed horizontally for the same diameters, the inlets need not be of large diameter. Also as provision can seldom be made for the cleaning of inlets, it is not advisable to construct expensive silt well inlets. Those constructed over the tile lines and directing the surface water immediately into the tile, and so constructed as to prevent clogging, the entrance of silt, and the washing of the soil surrounding the inlet, prove economical and efficient—inlet design, Fig. 10.

In cases where the tile line for other reasons cannot be located through the lowest points, the inlets may be constructed to one side of the line and connected to the tile line, as indicated by inlet design, Fig. 11. Where surface conditions allow, inlets should be located under fence lines and similar out-of-the-way places, so that farming operations will be least interfered with, and when placed in a cultivated field they should be marked with a number of large stones to protect them from injury. Aside from the advantages of simplicity of construction, minimum cost, and efficiency of inlets placed directly over tile lines, they prove very convenient for the inspection of the interior of the tile line, and should be located at convenient intervals for this purpose alone if they are unnecessary for the collection of surface waters.

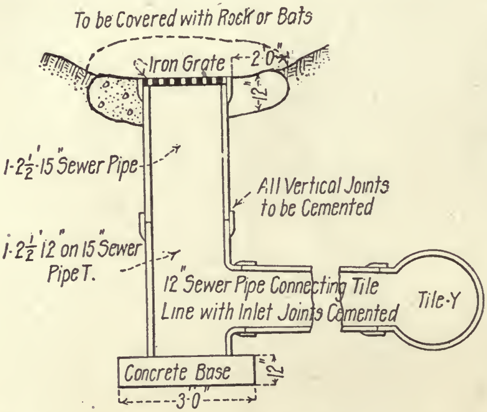

To be Covered with Rock or Bats
Iron Grate
2'-0"
12"
1-2½'-15" Sewer Pipe
All Vertical Joints to be Cemented
1-2½' 12" on 15" Sewer Pipe T.
12" Sewer Pipe Connecting Tile Line with Inlet Joints Cemented
Tile-Y
Concrete Base
12"
3'-0"

Fig. 11—Design for Inlet Located to One Side of Tile Line

The serious difficulty of constructing tile inlets which will be reasonably self-maintaining is not an imaginary objection to their use; it is especially an objection when means cannot be provided for proper supervision. The most serious problem connected with the construction of inlets is that of compressing the loose earth around them so as to prevent it from settling away from the concrete, thus allowing surface waters to be diverted under the concrete and wash through the surrounding soil to some joint in the tile. This tendency may be largely overcome by flooding or otherwise thoroughly compressing the surrounding soil. Even with these precautions, periodical inspection and repairs are necessary. The view shown by Fig. 12 clearly typifies the nature of the failure to which inlets are subject. If for any reason the soil cannot be satisfactorily compressed around the inlets, it is best to substitute broken rock or tile bats for the rim of concrete, on the theory that such filling will automatically settle with the earth. Also, in cases where there is a tendency for weeds, grass, and other rubbish to wash over the top of the inlet and clog it, a woven wire cage or fence should be constructed around and attached to the bell of the sewer pipe. The rubbish thus diverted from the grate furnishes additional material to become compacted around the inlet and prevent the washing out of the surrounding earth. In addition to their value as a means for the rapid removal of surface waters, properly maintained inlets also often effectively accomplish the flushing of accumulated silt from tile lines because of the additional pressure exerted.

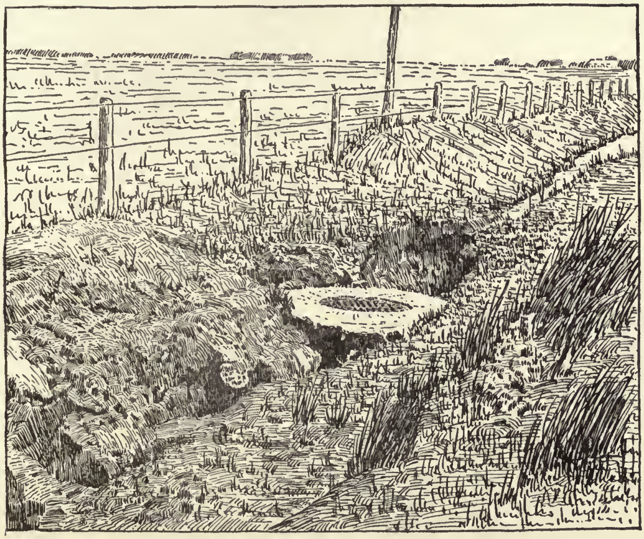


Fig. 12—View of a Washed-out Inlet

CHAPTER IV

DESIGN AND MAINTENANCE OF OPEN DRAINS

Depth of Ditches.—For the successful drainage of the larger watersheds, which cannot be economically drained by tile mains, artificial ditches must be constructed for outlet purposes unless a channel of sufficient size and capacity and of reasonable straightness has been already formed by natural agencies. The minimum requirements of tributary tile mains must largely govern the depths of open drains. After these requirements are complied with, such variations as to grade, depth, width and slopes may be made as the soil conditions, topography, and the quantity of water to be removed, may demand or allow. In districts where all necessary tributary tile mains are not included as a part of the proposed enterprise, the lengths and necessary fall should be closely estimated for all such lines and the location of their points of discharge and their outlet elevations should be noted on the profile. Those lines requiring the lowest outlet elevations necessarily arbitrarily fix the minimum depths of ditch possible.

Minimum Depth of Ditches.—Because of the universal tendency of ditches with flat gradients to collect silt and rubbish, and as branch tile lines of flat grades cannot successfully drain adjacent lands when discharging below the level of the water in the ditch for extended periods of time, all ditches should be designed of greater depths than the minimum outlet requirements of tile mains demand. The erosive nature of the soil, the gradient, and the level of the water in the ditch at times of severe rains, largely determine the extent of this depth factor of safety. In case of ditches constructed through substantial soils, as clay or hardpan, and of minimum grades of 4 ft. per mile, the elevation of the lowest tile outlets should be at least 2 ft. above the base of the ditch. Small ditches of gradients less than 4 ft. per mile tend to fill above the planned grade line even in the most stable soils, and the period of time they may be maintained without expensive reconstruction may be materially increased by planning additional depths of 3 ft. or more. The view, Fig. 13, indicates the submerged condition of a tile outlet into an open drain of gradient of 4 ft. per mile constructed in a clay-loam soil two years after the construction of the ditch, the grade of the tile outlet having been originally on the same level as the grade of the ditch. The accumulation of about 2 ft. of silt in this time is indicative of the general tendency of open drains to silt rapidly during the first few years after construction.

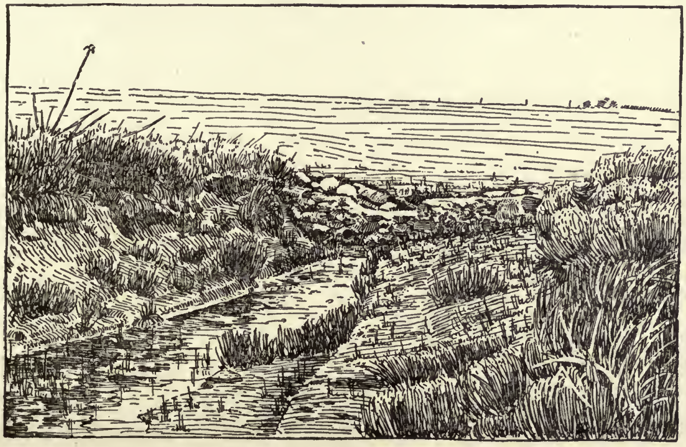


Fig. 13—View of a Submerged Tile Drain Outlet into an Open Drain

In order that ditches may prove effective as tile drain outlets and be reasonably permanent, the least depth of open drains in any case should not be less than 6 to 7 ft. The adoption of this minimum depth standard excludes the planning and construction of capstan or plow ditches; because of the facts that capstan ditches rarely exceed 2½ to 4 ft. in depth, 1½ to 3 ft. in base width, and cannot be successfully constructed to grade, but must be constructed of practically uniform depths throughout, their use is seldom practicable in drainage enterprises. However, the owners and promoters of capstan machines and ditches often induce groups of land owners to install these ditches on the plea that sufficient outlets for lateral drains will be effected at a nominal expense. The only instances where these ditches are practicable are in the case of steeply sloping draws where the surface gradient is fairly regular and the side slopes of the valley are of such elevations that shallow outlets will suffice for lateral tile drains.

Depth of Ditches in Unstable Soils.—The proper minimum depths of ditches to be constructed through shifting soils, as sand or peat, cannot be so definitely decided. Such sub-soil strata of sand overlaid with denser soils render ditch construction and maintenance extremely difficult of accomplishment as the sand stratum invariably contains sufficient water to render the sand semi-fluid and cause it to flow toward the center of the ditch as rapidly as excavated. This results in the undermining and caving of the berms and waste banks during construction, causing a general disfigurement of the ditch during successive cuttings by the dredge without any appreciable gain in depth. The view in Fig. 14 shows the general appearance of a ditch constructed under such conditions. A more permanent ditch can be constructed under such conditions by planning the grade line just above the sand stratum if the outlet requirements can be reasonably complied with by such a design. When sand strata must be penetrated a greater depth than necessary under normal conditions should be specified and methods of construction required which will most effectively insure successful construction.

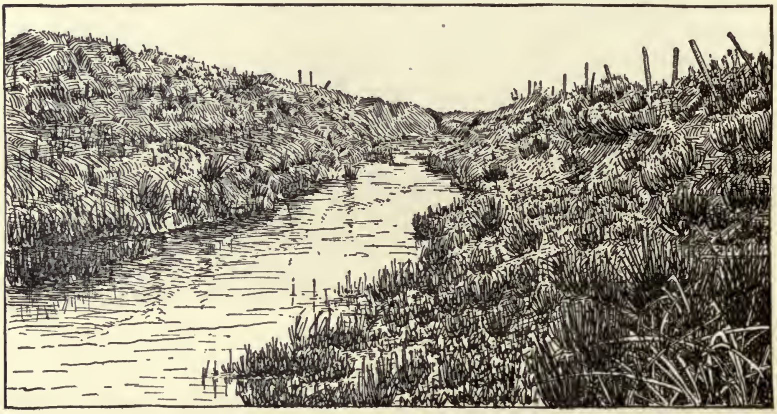


Fig. 14—View of a Deep Open Drain Through Sandy Sub-soil

The problem of designing ditches through peat beds differs in that the troublesome material is found at the surface and the difficulty of securing permanent depth arises from the tendency of the slushy soil to flow into the ditch during construction and of the peat to settle after construction and thus reduce the depth of the ditch. In this case provision must be made for excavating at least 2 ft. of depth in addition to the 2 to 3 ft. of additional depth required as an outlet factor of safety. These excess depths necessitated by the conditions of flat gradients combined with either ordinary or semi-fluid soils become less necessary as the rate of grade increases.

Adjustments of Gradients.—The required elevations being thus fixed on the ditch profile in accordance with the limitations of outlet requirements, soils and grades, the grade lines may be planned for the entire ditch. With due consideration being given to the presence of sand strata and outlet requirements the grade should be sufficiently uniform to avoid abrupt changes of rate of fall from steep to flat, as grades greater than 4 to 6 ft. per mile result in more or less erosion of the channel and the consequent depositing of the suspended matter in the portion of the ditch having a less gradient.

It very seldom occurs that ditches designed with such depth factors of safety as here advocated will be so shallow that excessive base widths will be required, with consequent retarded velocity and filling action, unless the outlet limitations are such as to necessitate such a design. In such cases the general rule that velocities and scouring action increase with depth and narrower bases should be held in mind, and where other conditions do not interfere, the proper adjustments of depth and base widths should be made to provide the velocity which will not result in excessive erosion of loose soils or the filling of the ditch.

Watershed elevations are sometimes such that a deep outlet is necessary for a lateral watercourse at some particular point along the ditch while the tributary lands above this point are on a higher elevation which may be drained by a shallower ditch. Thus it is necessary to plan a sufficient gradient from the upper end of the drain to some point above the lateral outlet and distribute the excess fall over the short intervening distance to the point of outlet, to plan a regular grade from the upper end to this point necessitating a large amount of unnecessary excavation, or to provide an abrupt drop in the grade line at the desired point by the construction of a dam across the bottom of the ditch. In case the deeper excavation required in the second case should extend into loose, sandy soil which would erode rapidly a dam is advisable, providing it can be so substantially constructed that it will not become displaced and the ditch above the dam eroded by natural action and the eroded material deposited in the lower reaches of the channel, a fact which has not yet been satisfactorily demonstrated. The first method may be safely used if the penetrated soil is stable and sufficient fall can be provided in the lower parts of the ditch to prevent its silting from the erosion that does occur and the outlet of lateral drains thus impeded. The second plan is practicable provided that serious erosion does not occur in the upper portion of the drain. The third method is justifiable in cases of dangerously erosive soils above and when proper inspection and maintenance can be provided for.

A combination of grades changing from steep to flat and back to steep should be planned only under extreme necessity as the tendency must be either for the current to deposit silt on the flat grades or to erode away the artificial hump.

Side Slopes of Ditches.—The rate of side slope that should be designed for open ditches depends principally upon the stability of the soil, although consideration should be given to the method of excavation that will be the most feasible in each case. The angle of repose of soils varies with the degree of fluidity of the soil when mixed with water and unless this angle is approached in ditch construction the caving of the banks is certain to result. As the invariable erosive action of running water in open ditches is to wear away the lower corners of the channel, eventually reducing the cross-section to a rectangular or U-shape, it is not advisable to plan ditches of too great side slopes as all excess soil in the lower corners of the ditch must finally erode and silt the ditch or be carried beyond the ditch and deposited. On the contrary, if the slopes are too abrupt for the character of the soil, the upper edges of the ditch will first erode into the ditch and later, after the edges have become sodded and more stable, the ditch will wash out and fill to its final form. Thus the design of slopes should be based upon an investigation of the soil which will ascertain as nearly as possible the slope at which the edges of the ditch will remain stable as constructed and yet as little earth as possible will remain in the lower corners of the ditch for future displacement. The proper slopes to accomplish these results vary from ½ horizontal to 1 vertical in very stable soils to 2 to 1 for the sandy and gravelly soils, a slope of 1 to 1 being generally satisfactory for average soils.

As the greater per cent of open ditches are constructed by floating dredges it is difficult to enforce flat side slopes, as it is difficult for dredge crews to shape invisible slopes, and as a result they usually tend to approach vertical slopes. Ditches to be thus constructed should be planned with as slight slopes as allowable and the plans rigidly enforced, or provision made for construction by dry land machines by the use of which slopes can be more accurately shaped.

Width of Berms.—The proper width of berm or clear space to provide between the edges of the ditch and the inside edges of the waste banks also depends largely upon the stability of the soils and the weight of the waste banks. As the average practicable excavating machine is not constructed to economically remove the waste a greater distance than necessary to leave a clear berm of 6 to 8 ft., it is usually best to limit the requirements to these widths and specify the proper slopes and standards of construction to prevent the caving of the berms as much as possible. In case of very large deep ditches the excavated material from which forms extensive and weighty waste banks, widths of berms should be fixed at 8 to 12 ft. depending upon the stability of the supporting soil and the machinery required capable of removing the waste to such distances successfully.

Computations to determine the weights of waste banks in given cases illustrate clearly the tendency of the sides of ditches to slide because of the superimposed weights, especially if the cohesion of the soil is at a minimum as in the case of wet sandy soils. For instance, the weight per lineal foot of waste bank of a ditch of 20-ft. base, 1 to 1 slopes and 20 ft. in depth, equals 1,481 lbs., wet earth being figured at 100 lbs. per cubic foot. As the line of cleavage of the wedges of soil which tend to cave from the sides of any trench is always of a curved shape, if the waste banks were deposited outside the surface extremity of this cleavage line their sliding effect upon the ditch banks would be entirely prevented. To the author's knowledge this distance has not been experimentally determined, but experience indicates that waste banks deposited at the suggested distances would probably closely fulfill this requirement.

Base Widths and Necessary Capacity of Open Drains.—A particularly important corollary of the foregoing features of open ditches is the base width which, together with the depth and gradient, controls the capacity of the ditches and their consequent success or failure. Because of the aggravated filling action in ditches serving the smaller watersheds ranging from 1,000 to 4,000 acres, the minimum base width of ditches should not be less than 8 ft. Also as dredging outfits must necessarily be built for the construction of ditches of average widths there are very few in use small enough successfully to excavate ditches of less widths. Contractors securing ditches of the narrower base widths, naturally tend to excavate channels of the required top width and about 8-ft. bases, thus leaving too perpendicular side slopes. Hence it is more practicable to receive bids on ditches designed with the wider base widths; more satisfactory side slopes are insured, and ditches are secured with safer margins of capacity to offset the inevitable excess filling incident to the smaller watersheds' insufficient water and resulting lack of pressure in the ditches over the necessary periods of time to render them self-cleaning. The base widths of ditches draining watersheds of greater extent are necessarily determined by the amount of water to be removed in a given time, a factor which has generally been assumed by means of a process of intelligent guesswork owing to lack of data and the uncertainty of influencing conditions upon the rate of run-off.

Depths of Removal to Be Provided For.—A general standard of run-off must be arbitrarily assumed based upon the most reliable information obtainable as in the case of tile drains, and similarly this rate of removal must be varied to compensate for unusual conditions of soil, topography and rainfall. Although in a measure guesswork these influencing conditions may be closely approximated for given cases. The United States Department of Agriculture from river measurements and rainfall records adopted a standard rate of run-off of 3/16 in. in depth in 24 hours from the larger sub-watersheds of approximately 100 square miles and ½ in. from the smaller watersheds as a basis for planning suggested drainage improvements along the West Branch of the Des Moines River. This depth of removal may safely be adopted as a standard average for watersheds of similar rates of maximum rainfall—of 4.39 ins. in 24 hours and 8.56 ins. in one month—and similar topography—slightly rolling, with average watercourse slopes of 2½ to 3 ft. per mile.

Where the means are available during the survey of the larger districts, records should be kept of natural stream discharges over as long periods of time as possible and the known discharge of similar watersheds should be investigated and compared. Although a large number of ditches have been constructed for the smaller watersheds of only sufficient capacity for the removal of $\frac{1}{4}$ in. in depth in 24 hours, and sometimes even $\frac{1}{8}$ in., with surprising success in the more level districts, these ditches in time have demonstrated their failure as outlets for lateral drains. Such ditches, lacking any excess capacity at times of unusual rainfall, are taxed to their full capacity over extended periods of time, and thus seriously restrict the discharge of tile mains which are later constructed as outlets for adjoining low lands. As a result these ditches serve efficiently as overflows for surface waters, but fail to accomplish their more important function of making possible the permanent reclamation of valuable soils by tile underdrainage.

Discharge and Velocity Formulas.—A number of formulas have been developed for ascertaining the velocity and discharge of open ditches, but for reasons heretofore enumerated in the discussion of tile drain formulas the Chezy-Kutter formula is probably the most practicable. Based upon a value of n of 0.030 the value of c may be taken from Table V, which is rearranged from tables in Trautwine's Pocketbook and the velocity computed from the Chezy formula, $V = c\sqrt{r\,s}$. It is evident from the table that the value of c varies very little for slopes ranging from 0.001 to 0.01, so that the tabular value of c opposite 0.001 for greater slopes will give accurate results. With r computed in feet the discharge in cubic feet per second equals the area of the waterway multiplied by the velocity and the acreage value of this quotient for any desired depth of removal may be computed by dividing it by a decimal as in the case of tile drains. The value of s may be taken from Table VI. The value of r for any given section of ditch may be computed from the formula:

$$r = \frac{D\,(B + SD)}{B + 2\sqrt{D^2 + (SD)^2}}$$

where D = Depth of ditch from desired water level.
B = Base width.
S = Rate of horizontal to vertical slope, as 1, 1, $\frac{1}{2}$, etc.
r = Mean hydraulic radius.

In using any formula for determining the size of ditches, a factor of safety of capacity should be allowed for which will result in maintaining the depth of water in the ditch at a level low enough to permit the efficient discharge of lateral tile lines. The additional capacity necessary for this purpose is dependent upon the topography of the side lands adjoining. If they are gradually sloping upward from the ditch banks in such a way that all tile lines are furnished sufficient head to prevent the serious restriction of their discharge into the ditch when it is running to its full capacity, the additional capacity need be only enough to maintain the water level 6 in. to 1 ft. below the edges of the ditch at points of least depth when running to its full computed capacity. This factor of safety should be increased, where more level lands are concerned, enough to maintain the water level at least 3 ft. below the surface level of the lowest ponds in the adjoining watershed. A greater margin is preferable to insure satisfactory tile underdrainage, but in no case should this standard be encroached upon unless the outlet conditions are absolutely prohibitive.

Factors Affecting Run-Off.—This discussion thus far has related only to average agricultural watersheds. Where hilly, mountainous or impervious watersheds are concerned, the rate of removal must be increased to as much as 2 to 3 in. in 24 hours in extreme cases, and the capacity of drains designed accordingly. Each case must be investigated separately for influencing conditions. Other factors to be considered in fixing the rate of removal and capacities of ditches for any watershed are concisely summarized in Bulletin No. 230 of the United States Department of Agriculture, and this bulletin will largely be quoted in the discussion of these factors.

FACTORS AFFECTING RUN-OFF.

The chief factors affecting the rate and total amount of run-off are: Rainfall; topography; the size, shape and location of the watershed; evaporation, and the transpiration of plants; climate and seasons; soil and geological structure; natural reservoirs, and the storage capacities of streams; the proportion of forest and open land, and the nature of the vegetable growth; the manner of cultivation of farm lands, and the particular crops planted; and artificial improvements affecting drainage.

RAINFALL.

This is the most important element to be considered in the estimation of run-off. A region of heavy rainfall will also be one of heavy run-off; and the variations in rainfall must be reflected in the amount of water which reaches the outlet channels.

As run-off is directly dependent upon rainfall, and as the rainfall which may occur at any time cannot be determined within wide limits, it is seen that an exact determination of run-off is impossible. However, in order that drainage should be thorough, it must be sufficient in time of extreme storms; and if an examination of these indicates a certain uniformity of maximum rainfall, some intelligent conclusions may be reached as to the run-off to be provided for.

TOPOGRAPHY AND GROUND SURFACES.

It is very evident that hilly and mountainous land will have a greater rate of run-off during storms than will flat land, and, in fact, this difference is very marked in many instances. There are obviously no distinct lines between the different classes of topography, but in general three characteristic divisions may be noted.

First is the rugged or precipitous mountain and hill land, from which the run-off is torrential. Here the streams, which form narrow gullies between ranges of hills, have steep channel slopes of 2 to 10 ft. or more to the mile. The water which falls as rain finds its way to the gullies and watercourses, and within a few hours after falling is in the main channels on its way to the outlet. In such cases the extreme flood at the outlet from an area of 500 to 1,000 square miles may occur 6 to 24 hours after the heaviest rainfall. From such areas a run-off of an inch in depth over the entire watershed in 24 hours is not uncommon, while run-offs of 2 and even 3 ins. in 24 hours have been recorded. The second class includes areas which, while not uniformly precipitous, are rolling, have surface slopes of 10 to 50 ft. per mile, and are cut by numerous streams or gullies. Here the water gathers quickly after storms, and the extreme floods flow from areas of 500 to 1,000 square miles in one to three days after the time of greatest rain. From such areas, run-offs of ½ to ¾ in. from the entire watershed in 24 hours are not uncommon in the central United States, and run-offs of twice this amount sometimes occur. The third class includes flat lands having little or no appreciable surface slope. Here the maximum rate of run-off depends very largely upon other conditions which will be discussed, and may vary for areas of 500 to 1,000 square miles from 0.05 to 0.30 in. in 24 hours.

Aside from the general topography, the condition of the ground surface has much to do with the rate of run-off. A clean surface over which the water can find its way without difficulty, and one filled with gullies and small channels, will have a quicker run-off than a surface covered with loose rock and débris and having no well-defined channels for carrying water.

THE SIZE, SHAPE, AND LOCATION OF WATERSHED AREAS.

Large watersheds may be counted on as having lower rates of run-off than smaller ones: First, because most extreme storms are usually local, so that, where an area of 50 square miles may have a rainfall of 3 ins. in 24 hours, an area of 1,000 square miles during this same period will probably have an average precipitation of not more than half that amount. This localization of extreme rainfalls is so general that it may be depended on in calculating run-offs of very large areas; second, in a large watershed local conditions as to topography and other factors influencing run-off counterbalance each other. A small area may happen to combine many elements which tend to produce a large run-off, while in larger areas some parts will have larger run-offs than others, and that of the area as a whole will be less than that of portions having the more extreme conditions; third, the run-off of the various parts will never coincide exactly in point of time. That is, on account of the difference in length of time required to reach the outlet, the water falling nearest the outlet will pass away before that from a greater distance, and so the flood flow will be moderated. Formulas for estimating the rate of run-off according to the size of the watershed find their justification in these facts.

The shape and location of a watershed also affect the rate of run-off. A drainage area having a fan-shaped outline, with numerous tributary channels uniting to form an outlet at the small end of the fan, will have a comparatively high run-off, because water from the greater part of the area will be concentrated in the main channel. On the other hand, in a long, narrow drainage area the flow will be distributed over a longer time, on account of the difference in time required for the water in different parts to reach the outlet.

EVAPORATION AND TRANSPIRATION OF PLANTS.

As practically all water falling upon a drainage area either passes out of the district in its watercourses or is evaporated, it is seen that evaporation is a very important factor to consider in planning drainage improvements. While the knowledge of the subject is somewhat limited, it is believed that in the lower Mississippi Valley evaporation from water surfaces amounts to from 2 to 4 ft. in a year. The rate of evaporation is very much greater in summer than in winter, in windy than in still weather, and is more rapid from exposed surfaces than from those which are sheltered.

While studies and estimates of the water removed by growing plants have been made for many years, only the most general knowledge of the subject is available. It has long been noted in the warmer parts of the United States that when the leaves come out in the spring the water level in many streams and swamps begins to fall, while the dropping of the leaves in the fall is commonly accompanied by a definite rise of from a few inches to a foot or more in the water levels of streams and sloughs. Careful experiments have been made in France, southern Russia, and India to determine the difference in ground water level at the end of the growing season in tracts of forest and of cleared land lying side by side and similar in all other respects. It has been found that at the end of the growing season the ground water level in wooded tracts may be from 2 to 12 ft. lower than that of open tracts adjoining, this difference being due to the removal of water from the soil by forest growths.

In addition to the amount of water taken from the soil and evaporated from the leaves of deciduous forest trees, a considerable amount of the summer rainfall, estimated by forestry experts at perhaps about 40 per cent, never reaches the soil, but being caught by the leaves is again evaporated into the air.

It is seen, therefore, that the amount of rainfall to be carried away by the drainage system of a forested area is less for the entire year than from a similar area of cleared land; and that a drainage system which is abundantly sufficient for forest areas may be found to be too small when the land is cleared and put into cultivation. It often happens, however, that the surface of the soil dries out more quickly in cleared and cultivated land than in woods. This is because cultivated land usually has surface ditches or other provisions for carrying rainwater to run-off channels, and because the surface soil dries out quickly in sun and wind, whereas in woodland water taken up by roots is from the lower soil.

CLIMATE AND SEASONS (Condensed).

The run-off which must be provided for to allow of satisfactory cultivation of the soil will depend somewhat upon whether the time of occurrence of the rainy season is at a time when crops will be most damaged and also upon the temperature and probable rate of evaporation during the wettest seasons.

SOIL AND GEOLOGICAL STRUCTURE (Condensed).

The run-off from clay or other heavy soils will be largely in excess of the run-off under otherwise similar conditions from sandy, porous soils. In case of the sandy soils the flow is regulated over long periods of time because of the storage capacity and retarding influence of the soil and less ditch capacity is therefore required.

NATURAL RESERVOIRS AND STORAGE CAPACITIES OF STREAMS (Condensed).

When it is desirable to thoroughly drain all portions of a watershed there should be little credit allowed because of natural reservoirs, while the credit that may be allowed for storage in channels is generally negligible where the watershed waters are all diverted into main outlet ditches. In case it is practicable or desirable to regulate ditch flow or secure power by the use of storage reservoirs the total run-off may be materially diminished at critical times.

FORESTS.

The increase of evaporation due to forests has already been referred to. They tend to reduce moderate floods, moreover, by obstructing the water as it flows over the surface of the ground, requiring a longer time to reach outlet channels. In many parts of the South a cutting away of the forests has resulted in a vast amount of hillside erosion, and this, in turn, has caused floods to be more torrential.

Ditch Inlets.—There is a marked tendency for surface waters to wash openings in the waste banks and erode open channels in existing watercourses, depositing the silt in the ditch in the case of all ditches. Figure 15 is a view of a washout. The seriousness of the results of this tendency depends largely upon the character of the soil. If the soil is a stable clay or similar soil, the erosion will not be noticeable, and lateral watercourses may safely be allowed entrance into the ditch through openings left in the waste banks during the construction of the ditch. A view of an opening in a waste bank is shown by Fig. 16. Such openings when left unpro-

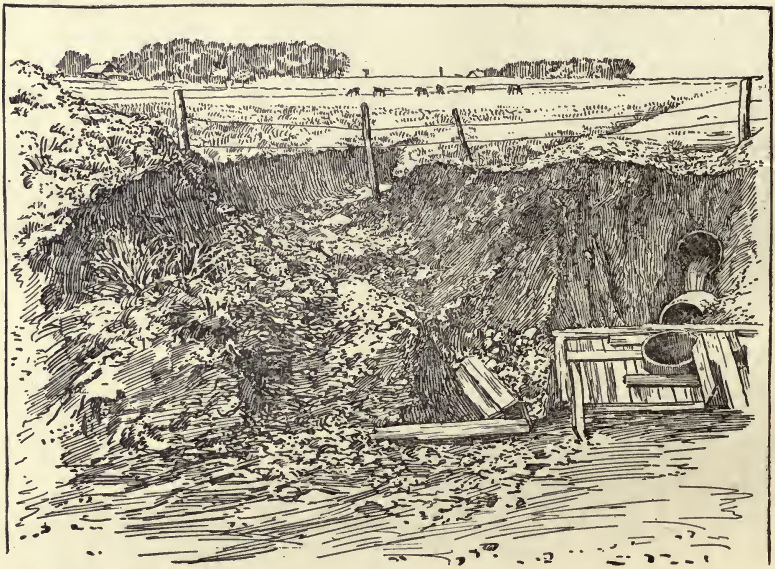


FIG. 15—View of a Lateral Wash-out Into an Open Drain

tected in loose-grained soils allow the erosion of washout channels for long distances, with disastrous effects. The flood waters from the smaller sub-watersheds may safely be diverted, into the ditch by inlets constructed in accordance with the design in Fig. 17, the size of the pipe being computed from standard culvert formulas. This design may be varied in order to allow outlets for future tile lines by replacing the steel pipe with a line of sewer pipe with cemented joints at the required depth or lowering the corrugated steel pipe, the wall being constructed at the ditch edge as an outlet wall and an inlet constructed over the line at the outside edge of the waste bank to provide an entrance for surface waters. The principal objection to this kind of design lies in the fact heretofore referred to, that flood waters tend to wash away the soil surrounding the inlet and tile line.

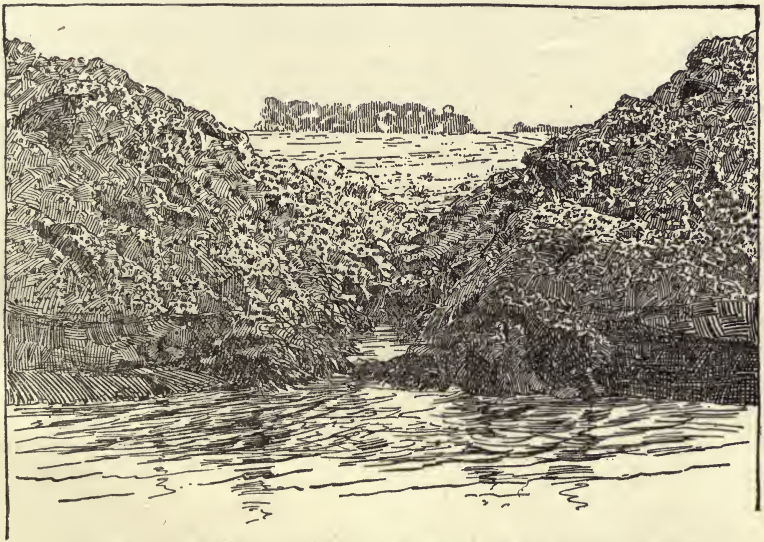


Fig. 16—View of an Opening in a Waste Bank for Surface Waters

When watersheds of greater extent are to be contended with, which drain into channels whose grade lines are on a higher level than the grade line of the main ditch at their intersection, and the soil is subject to erosion, a different protection structure is necessary. The point to be held in mind in the design of a drop-wall or spillway for such cases is stability of the structure to prevent the flood waters from undermining or cutting around the wall at times of greatest pressure. Should the lateral drains be constructed as a part of the undertaking, their grade lines may be sloped sufficiently to connect with the grade line of the main, unless this plan is objectionable for other reasons.

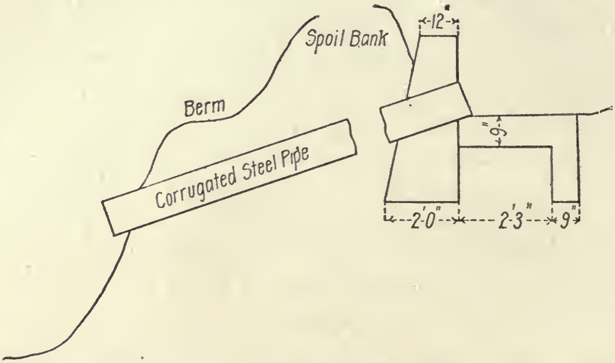


Fig. 17—Design of Ditch Inlet

Maintenance of Open Drains.—Open drains designed with ample depth factors of safety, and effectively protected from washouts, should require little maintenance for considerable periods of time. The common history of the earlier open drains in most communities, however, has been that the necessity for ample depth and capacity was not realized at the time of their construction, and that constant repair work is necessary to retain even a measure of their usefulness, and in many cases a complete reconstruction is essential. Forces of nature are constantly in operation which tend to fill open drains, and in the course of time all of them will require maintenance expense, the length of time and amount of expense depending upon the efficiency of the original ditches. As tile drainage becomes more extensively practiced in any community, the more insistent are the demands for deep, well maintained open outlets. The period of time in which an open drain is subject to the most pronounced filling action is during the first year after construction, when the waste banks, berms, and slopes are still in a loose, unsettled condition and readily affected by the weathering action of water and frost. During this time silt is collected by these natural agencies, and unless the gradients are steep enough to allow of the carrying of a large amount of sediment in suspension, ditches become filled above the excavated grade line for depths of 1 to 2 ft. and oftentimes 3 to 5 ft. in loose soils. After the soil composing the waste banks, berms, and slopes has become compacted and has more nearly assumed its permanent form, the filling from these sources becomes largely diminished. Other sources of filling after this period has elapsed are: the growth of moss, weeds, grass and trees in the base and on the slopes; the formation of silt bars across the base of the ditch, caused by the washing in of the banks or the temporary formation of a dam by vegetable matter or other obstruction which serves to retard the velocity of the current and cause it to deposit silt at this point. The proper system of maintenance is a provision for periodical inspection and repair of all open drains, but this plan has seldom been practiced even in those localities where the state laws have specifically required inspection. As in the case of the public highways, the maintenance of open drains will be generally neglected until officials are provided whose express duty shall be to superintend this work, who shall be under bond, properly qualified, and provided with the financial means for the prosecution of the work.

Methods of Deepening and Cleaning Ditches.—There has been in the past so little open drain maintenance work prosecuted that tried satisfactory methods of accomplishing the work have not been developed. If the deepening of an open drain is required of 4 ft. or more, a floating dredge may be economically used if the quantity of work is extensive enough to warrant its installation, or a traveling platform may be constructed to be propelled along the ditch banks, carrying the necessary machinery for the operation of a boom and

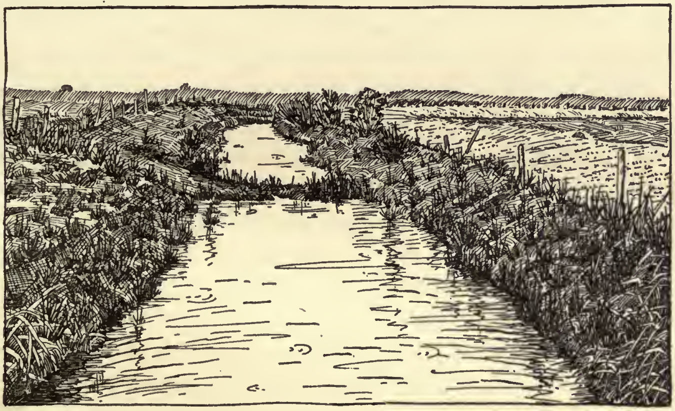


FIG. 18—View of a Silt Bar in the Base of an Open Drain

bucket or some form of drag-line excavator. Bars in ditches may be removed in dry seasons by scraper or even by hand labor, or so loosened when the ditch is running partially full by a scarifier consisting of a framework built across the ditch, carrying cultivator shovels or similar devices pulled by teams on the banks, that the sediment may be transported by the current. Figure 18 is a view of a bar formed in a ditch, the bar being of sufficient height to render useless a large percentage of the ditch capacity, and which, like many bars formed in this manner, could be readily removed, but is allowed to remain because of neglect on the part of adjacent land owners and public officials charged with the supervision of drainage matters. Another method for the removal of nominal amounts of sediment in ditches, which has been tried in a few cases with considerable success, is the use of a suction pump mounted upon a platform and floated in the ditch. However, the immediate problem in most communities for some time will be the development of a public realization of the economy of ditch maintenance, and when the necessity is fully realized methods will speedily be evolved for accomplishing the work.

Types of Suitable Open Drain Bridges.—The deepening and recleaning of open drains is in many cases handicapped and the cost greatly increased because of the character of bridges that have been constructed. Too often bridges have been built with abutments so closely spaced and with foundations carried to such shallow depths that floating dredges cannot readily pass between the abutments, and that deepening will result in the undermining of the foundations. All bridges spanning newly constructed open drains should be planned with ample clearance between abutments to allow the passage of any excavating machinery that might be used in the future, and the foundations carried to such depths as to insure their permanency. The bridge decks should be constructed so as to be removable from the abutments. A practicable plan to follow in the construction of bridges over open drains is the use of wooden piles driven well back from the ditch edge and steel I-beam floor girders carrying a plank floor. The pile abutments will last a sufficient length of time to determine the necessity of deepening or recleaning, and after such repairs, if they are necessary, permanent concrete abutments could be substituted.

TABLE V—VALUES OF C FOR DIFFERENT HYDRAULIC MEAN RADII AND SLOPES. N = .030

RADII. Slopes	.10	.15	.20	.30	.40	.60	.80	1.00	1.50	2.00	3.00	4.00	6.00	10.00	20.00	50.00	100.00
.0004 or 2.112′ per mile	19	23	25	30	33	38	42	45	50	54	59	63	69	75	83	91	96
.0010 or 5.28′ per mile	21		27	30	34	39	42	45	50	54	59	63	68	74	81	89	94
.01 or 52.8′ per mile	21	24	27	31	35	39	43	45	51	55	59	63	68	74	80	87	91

TABLE VI—FALL IN FEET PER MILE REDUCED TO DECIMALS

Feet per Mile	Decimal	Feet per Mile	Decimal	Feet per Mile	Decimal
1.5	.00028	6.0	.00114	11.0	.00208
2.0	.00038	6.5	.00123	11.5	.00218
2.5	.00048	7.0	.00133	12.0	.00227
3.0	.00057	7.5	.00142	12.5	.00237
3.5	.00066	8.0	.00151	13.0	.00246
4.0	.00076	8.5	.00161	13.5	.00256
4.5	.00086	9.0	.00170	14.0	.00265
5.0	.00095	9.5	.00180	14.5	.00275
5.5	.00100	10.0	.00189	15.0	.00284
		10.5	.00199		

CHAPTER V

PLANS, REPORTS AND RECORDS

Private Systems.—Maps, profiles and other plans of drainage systems are prepared to picture and record in permanent and usable form the actual conditions and proposed methods of bettering these conditions. Only the data necessary to accomplish this purpose should be included in the plans. In essential details these records are similar for all drainage systems, but because of special methods of procedure required in cases of legal organizations the plans proper for private drainage systems will be considered separately from those for drainage districts.

Maps for Private Systems.—Maps illustrating farm systems, besides the necessary arrangement of lines to distinguish section, quarter section and sixteenth section lines, should show the main tile lines and all laterals, closely scaled as to lengths and locations, the watershed boundary line, the acreages included from each separate tract of land, the names of the property owners, and the outlines of all ponds, swales and watercourses. The location of main tile lines should be tied in to known corners and lines by angles and measurements so that they may be readily relocated when necessary. The notation of all intersection stations of laterals with mains and the accurate laying off of the angles of laterals with mains and the scaling of their lengths will reference their location with sufficient accuracy. Each main and lateral may be designated by distinguishing numbers or letters, and the sizes of tile noted on each line at intervals along their courses for convenience in reference.

Simpler and more presentable maps result by omitting such detailed information as lengths of each line and of each size of tile and tabulating them elsewhere. Also on areas for which thorough tile systems are planned numerous elevations and pond and wet land symbols are non-essential, as these data are depicted on the profiles. However, such data should be shown on all tributary lands in the watershed not included at the time for thorough drainage in order that their comparative elevations at determining high and low points and topographical conditions may be apparent for purposes of record, designing, and division of costs. In cases where contour surveys have been made the engineer should prepare a contour map for designing purposes, but should omit the contour lines on the more intelligible plats which should be prepared for his clients.

Profiles for Private Systems.—The profiles for farm systems should show the details of ground lines, grade lines, stationing for lengths of lines, vertical elevations, rates of gradients, main and lateral numbers, and the depths of cuttings at all stations. A statement of sizes of tile, lengths of each size and average depths of each section of a given size, prepared and shown in tabular form, is properly included on the profile sheet. A record on the profile of the total number of feet of each size of tile required is also convenient for reference in the ordering of tile. A detailed description of the assumed bench-mark to which all elevations are referenced and of all other bench-marks established should also be entered upon the profile sheet.

As in the case of all drafting work, the appearance of plats and profiles is so greatly enhanced by neatly prepared titles that the time spent in their preparation is more than amply repaid in the prestige they create. If retaining walls and inlets are included in the design of the system, it is advisable to draw them upon the profile sheet, thus presenting all essential information upon the plat and profile drawings and reducing the number of plans to the minimum of simplicity for usage, filing and transferring with deeds.

Importance of Preservation of Plans.—Land owners too generally have not appreciated the importance of requiring and preserving plans. The percentage of land owners in any locality who possess any dependable record of the tile installed upon their farms is relatively small, this being particularly true after the land has been transferred several times. Many difficulties arise because of the absence of such plans; among them are the inability of sellers to demonstrate to buyers that their land is tiled, and the impossibility of relocating tile lines when it becomes necessary to reconstruct, repair or add to the system. The ideal that should be recommended by engineers is the preparation of complete plans before the commencement of the work of construction and the later attachment of the engineer's certificate stating the completeness of the work, such records being recorded and transferred together with other evidences of ownership.

Drainage District Systems.—Detailed data should be shown upon the plans for drainage districts in essentially a similar manner as for private systems, excepting that the range of information and method of portrayal are governed by the provisions of the state drainage laws and the special purposes for which they will be used. All plats should show watershed lines, the accurate locations of open ditch and tile lines, the elevations of all ponds and low points on every 40-acre tract in the watershed, the approximate locations and areas of all ponds and sloughs, the locations of natural watercourses, the extent of lands subject to overflow, and other information in addition as required by local conditions or state laws. It is best to adopt simple topographical symbols to represent ponds and wet lands and to use only enough of land condition divisions to picture clearly the actual state of the lands with reference to drainage. Lands not represented as swamp or wet lands must necessarily be low or high lands, which need not be indicated by special symbols. The general elevations and slopes of such lands may be shown by a limited number of recorded elevations. A complexity of symbols representing crops, buildings and other unessential information should be avoided. It is advisable to show the locations of school houses and churches and other semi-public buildings for the convenience of contractors, land-seekers and others interested in locating the various portions of the district. Towns need be only generally located on the plat, as separate detailed town plats prepared on a larger scale are usually necessary.

Maps for Drainage Districts.—Every drainage engineer should endeavor to give character to his maps by making them intelligible and by the use of distinguishing drafting methods, as the inclusion of section numbers in small circles, the insertion of small circles at the intersections of all tile line tangents, the representation of open ditches by two parallel lines, the double underlining of all surface elevations, and the preparation of attractive titles, arrow heads to denote directions, and legends.

Where it is customary or required by legal statute that the responsibility of determining which lands of the watershed area shall be included for benefit assessment purposes shall rest upon the preliminary engineer, it is customary to show two distinct boundary lines upon the plat, one including all forties which will be benefited, and called a district line, and the other encircling all forties or fractions of forties in the

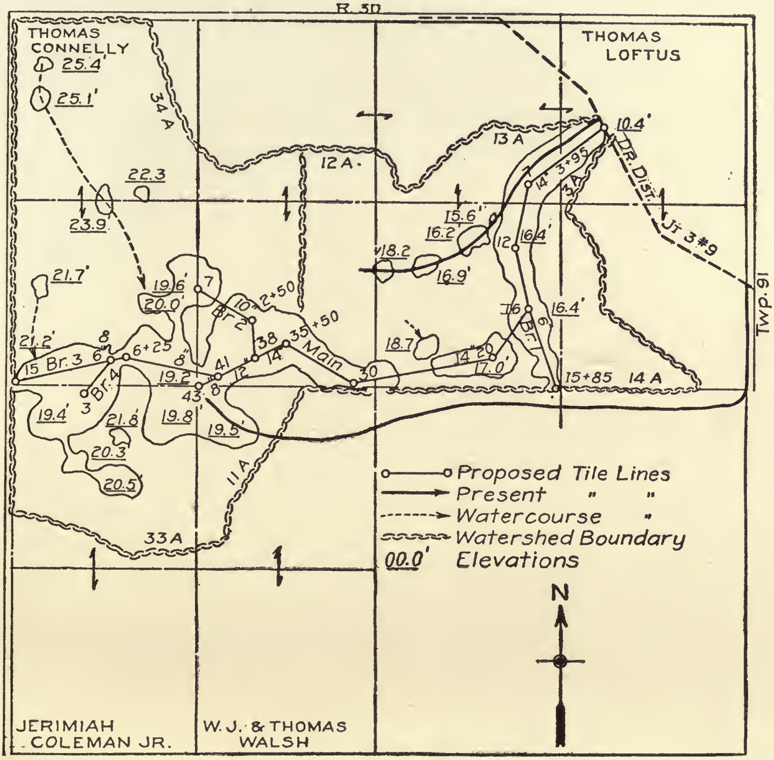


FIG. 19—Drainage District Map

watershed area, and called the watershed boundary line. A precise level survey is necessary to determine this arbitrary line between benefited and non-benefited lands. The basis upon which these different classes of land should be distinguished will be discussed in more detail in a following chapter. The extent and nature of forest lands as determined in the preliminary survey should in all cases be noted by the proper symbols, particularly when in close proximity to tile and ditch lines. It is also conducive to convenience in the field use of the map to print in the station numbers at all tangent intersections, the station numbers at intersections of tile and ditch lines with section and property lines, the station numbers at the intersections of branches and mains, the distinguishing number or letter of all drains, and to represent the locations of natural channels with reference to proposed drains. A portion of a drainage district map embodying these general rules is shown in Fig. 19.

Profiles for Drainage Districts.—Proper profiles for drainage districts differ little from those necessary for private systems, excepting that the lengths and sizes of ditch or tile line upon each farm or highway crossed and the names of all property owners should in all cases be shown either above or below the profiles proper. Also the plans for accessories are usually prepared upon separate sheets and records of benchmarks made in the typewritten report. In addition, the elevations of all highways and railroads crossed should be shown and large scale profiles prepared illustrating the details of railroad crossings. Cross-sections should also be drawn when necessary upon the profiles representing the shape and depth of old ditches which are crossed or followed with open or closed drains. Old ditches which are too narrow to allow the placing of the excavated material within the limits of the ditch

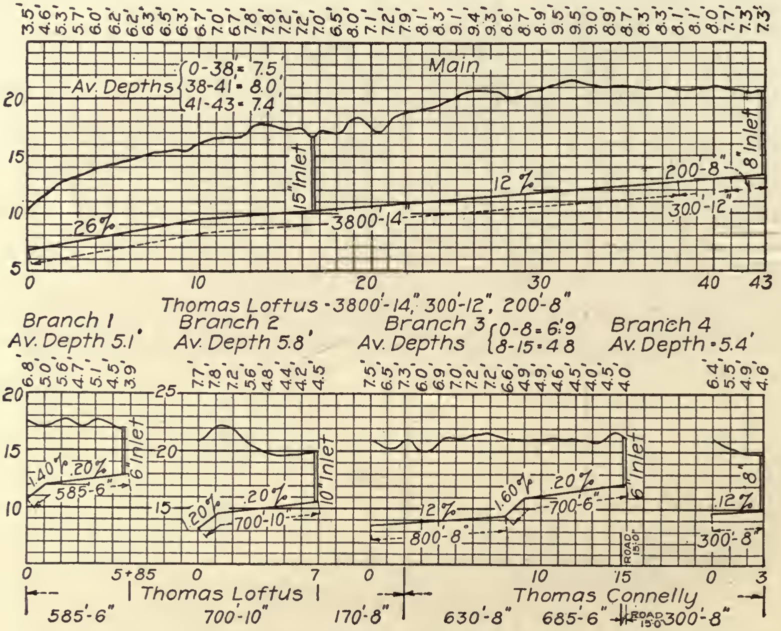


FIG. 20—Drainage District Profile

bases are of little or no advantage to tile trenchers nor to dredge crews, while broad ditches result in a material reduction of excavation in both cases. Contractors are often misled; favorably if in such cases the natural ground line is shown on the profile as the ground line, and unfavorably if the ditch base is shown as the ground line and no reference made to the existence, width and depth of the old ditch. Therefore, in justice, both the natural ground level and the bottom of the old ditch should be indicated, notations made as to which line the depths and averages are based upon, and typical cross-sections made showing the form of the old ditch. A representative drainage district profile is shown in Fig. 20.

Drainage District Reports.—Comprehensive reports of the findings and recommendations of the preliminary engineer are always required by law for drainage districts, and should be prepared for many of the private enterprises. As far as possible it is preferable to present all information in concise tabular form so as to be readily intelligible to land owners and contractors. The necessary items for inclusion will be referred to in their proper order, those being more fully analyzed elsewhere being stated without discussion. First in order are the findings of the engineer as to the condition of the affected lands, the feasibility and economy of the proposed project, his recommendations as to the advisability of proceeding with the improvement in accordance with the petition and survey, deferring action because of incidental unfavorable conditions, or the necessity of planning further extensions before proceeding. The value of this portion of the report must depend upon the ability, experience, sound judgment and fairness of the engineer. Following this should appear the descriptions of all routes of drains as to general locations in relation to land subdivisions, such specific information as to exact distances and angle referencing being included as is not proper or convenient to show upon the plat. Then in the following order should come information as to the area of watersheds tributary to each drain, bill of material, estimates of costs and damages, conditions of soil and effect of timber upon construction, average tile and coal hauls, records of all bench-marks, the kinds of excavating machinery practicable under the incidental conditions and the specifications. The bill of material properly includes tabulated statements of quantities of tile, number and sizes of sewer pipe, Y's, T's, grates, amount of concrete and quantities of all other materials necessary for the completion of the contract. The estimate of costs should be arranged in the proper order to present the facts of lengths, sizes, average depths, greatest depths, number and nature of accessories and estimated cost of each line separately, separate estimate items being shown for each section of a given size of tile and each accessory, the sum of the estimated contract price and estimated contingent expenses being totaled as the total estimated cost of the district.

The estimate of damages includes the items of acreages of land occupied by ditches, the value of the land, the cost of necessary bridges and fences, the estimated damages to adjoining lands, and the estimated damage, if any, to tributary lands below the outlet. In addition, other information necessary to fulfill the requirements of state drainage laws should be included, and all accompanying plats, profiles and other plans included as a part of the report by reference. A skeleton report is shown in Fig. 21.

Office Records.—The office records necessary to the drainage engineer will largely depend upon the nature and extent of the work under his direction, but in all cases should be such that he can locate any plat or notes with reference to any piece of work without delay. Note books for drainage districts may be identified by placing the number or name of the district upon the cover, and note books used for private surveys indexed upon the front pages. A more convenient method is to number all note books consecutively, also numbering the pages of each, and indexing every survey, whether for districts or private parties, by number, name and page, in a separate alphabetically indexed note book. In applying this plan, enough space is allowed in each note book used for a drainage district survey for all later construction notes, and the remaining space, if any, used for private survey notes or other drainage districts. If all notes are kept indexed in this way up to date, there will be practically no difficulty experienced in locating any desired notes.

Office Filing of Plans and Reports.—Maps, profiles and blueprints are best filed in cabinets, being indexed numerically, alphabetically or both by separate drawers or heavy paper divisions, or in the absence of such a cabinet, all plans prepared for certain districts or individuals may be rolled together and labeled, being filed in tin filing tubes or on

To the Honorable Board of Supervisors of .... County, ...

Having been appointed as preliminary engineer for drainage district No. ...., I have made a complete survey of the lands in the watershed of the proposed district and located the drain petitioned for and other drains necessary to fulfil the purposes of the petition and the wishes of interested property owners, and respectfully submit the following report and recommendations. ....

DESCRIPTION OF ROUTES.

Main: Commencing at the source, a point 1320 feet south and 35 feet west of the northeast corner of Sec. ...., thence in a general easterly direction to a point 35 feet north of the southeast corner of Sec. ...., thence ....

Br. No. 1: Commencing at a point ....

Extent of Watershed, Number and Size of Tile, Amount of Excavation, Number of Junction Tile, Etc.

There are 4380 acres in the watershed.
There are to be 64154 cubic yards of excavation.
There are to be 48405 feet of tile drain.

1500 feet of 22″ tile.
3900 feet of 20″ tile.
....
....
....

There are to be 5 retaining walls (see plans).
There are to be 4 ditch inlets (see plans).
There are to be 11 tile Ys: 1—12″ on 22″, ...

There are to be 34 sewer pipe Ts for connections of inlets to tile lines: 1—18″ on 22″, ...

There are to be 34 inlets requiring approximately 32 feet of 18″ plain sewer pipe, ..., 34 grates to fit the bells of the following sized sewer pipes: 7—18″, ... and sufficient concrete to encase the tops of all inlets as required by the plans.

Average Hauls.

The average haul for the open drain = 4 miles.
The average haul for the main tile line = 5 miles.

ESTIMATE OF DAMAGES.

Sec.	Owner	Acres Taken	Estimated Value of Land Taken	Estimated Cost of Fences and Bridges
Main.	....	3	$200.00	$100.00

ESTIMATE OF COST, OPEN DRAIN.

Sec.	Length	Base Width	Slopes	Average Depth	Cu. Yds.	Estimate
Main	4100′	8′	1 to 1	6.1′	13111	.13 per cu.yd.

4-ditch inlets	130.00
Damages	1800.00
Total estimate	10270.00

ESTIMATE OF COST, TILE DRAINS.

Sec.	Length	Size of Tile	Av. Depth	Great'st Depth	Estimated Cost	Totals
Main	2100′	20″	6.5′	7.3′	1860.00	....

Retaining wall	130.00	
5-inlets	65.00	4710.00

Br. No. 1...

Total estimate of tile drains.....................	25000.00
Estimated contingent expenses..................	3000.00
Total estimate cost of District..................	38270.00

SPECIFICATIONS.

....
Engineer

FIG. 21—Skeleton Drainage District Report

shelves, the rolls being grouped in such divisions by counties, numbers or letters, that excessive sorting will not be necessary to locate plans.

Carbon copies should in every case be preserved of all reports of whatever nature. Those that are not capable of form standardization, as preliminary and assessment reports, may be filed in filing boxes or box cabinets, such an arrangement being made that the papers for separate districts or owners may be grouped. Certain reports must be intermittently made during the progress of contracts which may be made on standard forms, as, for instance, the issuance of periodical estimates to contractors. Such forms may be made up in pads consisting of sets of three sheets, which sheets may be made up in different distinguishing colors if desired, two of each set being perforated for ready removal. A form for tile drain estimates is illustrated by Fig. 22, and a form for open drain estimates by Fig. 23. One copy of each estimate may then be filed with the owner or county, one with the contractor and one retained in the pad book by the engineer.

TILE DRAIN ESTIMATE.

..........................County, Iowa Date.................

District............ Contractor.................. Section........

From Station	To Station	Price per Lineal Ft.	Deducted	Amount of Estimate	80 per cent
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....
....	....	....	....	....	....

REMARKS:

....
Engineer

FIG. 22—Form for Tile Drain Contractors' Estimates

Progress Records.—A separate record book for the purpose of indicating the progress of the construction work on each project is a convenient aid in recording pertinent data and refreshing the memory at the time of filling out estimates. It is so ruled that the date, the number of feet of each size of tile rejected, the factory description of the tile being used, the amount of work completed, data as to extra work required or installed, and the initials of the engineer or his assistant may be entered for each inspection trip. Each project is given separate pages and indexed in the front of the book for reference. To avoid the necessity of carrying books of this kind during the field work, "Memo." slips similar to Fig. 24 may be carried and the data transferred at convenient times.

OPEN DRAIN ESTIMATE.

.........................County, Iowa Date.................
District............ Contractor.................. Section........

From Station	To Station	Yardage	Price	Deducted	Amount of Estimate	80 per cent
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....
....	....	....	....	....	....	....

REMARKS:

....
Engineer

FIG. 23—Form for Open Drain Contractors' Estimates

The drainage engineer who is in active charge of the construction of a number of drainage projects should devise some plan whereby he may be regularly informed as to the progress and status of each one, to avoid confusion and assist him in planning the routine of his work. The telephone is useful in cases where telephones are accessible to the foreman or inspector, but the tendency when this agency is depended upon is for foremen to neglect the supplying of information because of toll rates, the inconvenience of telephones and the absence of the engineer from his office. The postal card system, al-

MEMO SLIP.

Date	District No.	Number Feet Tile Rejected	Work Completed	Engineer

FIG. 24—Field Memorandum Slip for Field Inspection of Tile Drains

though subject to some of the same objections, is more effective. The cards may be furnished to the foremen, addressed, stamped and ruled on the back sides in a manner similar to Fig. 25 for tile drains and Fig. 26 for open drains. Then the foremen are reminded of the information desired by the headings on the card, and will, if impressed with the importance of filling out and mailing them weekly or oftener, generally mail the reports with reasonable regularity. Unless some systematic method is followed, the engineer may be ignorant as to whether the work is proceeding rapidly or slowly, whether the workmen are prosecuting the work or are laid off temporarily, whether tile are being regularly delivered, when the work should be again supervised, and other pertinent information which he should possess in order to plan his work to the best advantage and efficiently oversee the work.

FOREMAN'S REPORT.

Dist.No.	Tile Laid to Sta.?	Tile Hauled to Sta.?	Will Need Stakes?	Date
100	Main to Sta. 49 Br. A to Sta. 10	Main to 60 Br. A to 15 Br. B to 5	Wed., Mar. 6	Mar. 2

REMARKS:

FIG. 25—Form for Tile Drain Foreman's Report to the Engineer

FOREMAN'S REPORT.

Dist. No	Ditch Dug to Sta.?	Coal Hauled to Sta.?	Will Need Stakes?	Date

REMARKS:

FIG. 26—Form for Open Drain Foreman's Report to the Engineer

Reference Records.—The author keeps another office record book which might be called a historical and ready reference book, and which has proven to be a distinct time saver and a valuable guide in the investigation of other similar projects. In this book each project is assigned the necessary pages and properly numbered and described and indexed on the front pages. Then in order the following information is from time to time supplied: the description of each section of the work, the length, size, average depth, greatest and least depths, estimated cost, grade and tributary watersheds for all tile lines, the length, number of cubic yards, slopes, base widths, average depths, estimated cost, grade and tributary watersheds for all sections of open drains, the date of preliminary survey, the time of commencement of the work, the time of completion, the name of the contractor, a table of the contract prices, the kind of tile that is used in each tile section, the topography of the tributary watershed area of each section, the average hauls, nature of the soils encountered during construction, and general remarks.

TABLE VII—COST OF TILE, SPECIAL JUNCTIONS, SEWER PIPE, GRATES, CORRUGATED PIPES, ETC.

Diam. of Pipe in In.	CLAY TILE			CEMENT TILE		SEWER PIPE		Cost of Grates	Cost of Corrugated Pipe per Ft.	Cross Sectional Area of Pipe in Sq. In.
	Cost per 1,000 Ft.	Cost of Ys and Ts	Weight per Ft., Lbs.	Cost per 1,000 Ft.	Weight per Ft.	Cost per Ft.	Cost of Ts and Ys			
5........	$ 25.00	....	10	$ 25.00	....	....	....	....	....	19.63
6........	30.00	$ 0.20	12	35.00	.... ..	$0.09	$0.36	$0.30	....	28.27
7........	40.00	.25	15	43.00	....	....	....	.40	....	38.48
8........	55.00	.25	18	50.00	....	.15	.65	.40	$0.55	50.27
10........	85.00	.35	27	75.00	....	.20	.86	.60	....	78.54
12........	120.00	.45	36	100.00	42	.24	1.08	.90	.70	113.10
14........	190.00	.75	48	165.00	50	....	....	....	....	153.94
15........	230.00	.90	50	....	60	.37	1.67	1.50	.75	176.71
16........	260.00	1.00	60	240.00	85	....	....	....	.85	201.06
18........	360.00	1.87	70	300.00	100	.56	2.50	2.25	....	254.47
20........	500.00	2.50	90	360.00	116	.75	3.30	2.60	....	314.16
22........	575.00	2.88	110	420.00	142	.90	3.97	....	....	380.13
24........	675.00	3.38	124	540.00	186	1.05	4.75	....	1.30	452.39
26........	900.00	4.50	141	660.00	224	....	....	....	....	530.93
28........	1,050.00	5.25	190	750.00	251	....	....	....	....	615.75
30........	1,300.00	6.50	210	840.00	286	....	....	....	1.70	706.86
32........	1,450.00	8.75	222	960.00	320	....	....	....	....	804.25
36........	1,800.00	10.80	300	1.200.00	400	....	....	....	2.25	1,017.88

TABLE VIII—WIDTHS AND YARDAGES OF TILE TRENCHES

SIZE	3′		4′		5′		6′		7′		8′		9′		10′		11′		12′	
DEPTH	Width	Cu. Yds.	Width	Cu. Yds.	Width	Cu. Yds.	Width	Cu. Yds.	Width	Cu. Yds.	Width	Cu. Yds.	Width	Cu. Yds.	Width	Cu. Yds.	Width	Cu. Yds.	Width	Cu. Yds.
5 and 6″	12″	11.1	14″	17.2	18″	27.8	18″	33.3	20″	43.0	20″	49.2	22″	61.0	22″	67.8	24″	81.5	26″	96.0
7 and 8″	14″	12.9	16″	19.7	19″	29.3	19″	35.1	21″	45.4	21″	51.9	23″	64.0	24″	74.1	26″	88.0	28″	103.6
10″	16″	14.8	17″	21.0	20″	30.7	20″	36.9	22″	47.4	22″	54.2	24″	66.7	25″	77.0	27″	91.7	29″	107.6
12″	18″	16.7	18″	22.2	21″	32.4	21″	38.9	23″	49.8	23″	56.9	25″	69.3	26″	80.0	28″	95.0	30″	111.1
14″	20″	18.4	20″	24.6	22″	33.9	22″	40.7	24″	51.8	24″	59.3	26″	72.0	28″	86.3	30″	101.9	32″	118.2
15″	22″	20.3	22″	27.1	24″	37.0	24″	44.4	25″	53.9	26″	64.0	28″	77.7	30″	92.6	32″	108.4	34″	125.8
16″	24″	22.2	24″	29.6	26″	40.0	26″	48.0	26″	56.0	28″	69.0	30″	83.3	32″	98.5	34″	115.3	36″	133.3
18″	26″	24.0	26″	32.0	28″	43.1	28″	51.8	28″	60.4	30″	74.1	32″	88.7	34″	104.8	36″	122.2	38″	140.4
20″	28″	25.9	28″	34.5	30″	46.3	30″	55.5	30″	64.8	32″	78.8	34″	94.3	36″	111.1	38″	128.7	40″	148.0
22″	30″	27.8	30″	37.0	32″	49.3	32″	59.1	32″	69.0	34″	83.8	36″	100.0	38″	117.0	40″	135.7	42″	155.6
24″	32″	29.6	32″	39.4	34″	52.4	34″	62.9	34″	73.4	36″	88.9	38″	105.3	40″	123.3	42″	142.6	44″	162.7

CHAPTER VI

THE ESTIMATE OF COSTS OF DRAINAGE SYSTEMS

Elements of Cost.—The estimating of total approximate costs of drainage systems is a comparatively simple matter, as the various cost items are few in number and may be closely estimated from local retail price lists and prevailing contract prices for similar work, providing considerable drainage work is being accomplished in the neighborhood. But of more import to contractors or bidders are the peculiar conditions or obstacles to be encountered during construction which will tend to increase or decrease the cost as compared to average costs. Therefore intelligently to estimate costs, drainage engineers must be familiar with and recognize the items of cost which must necessarily be considered by contractors and should deduce estimates from the contractor's standpoint, both for the purpose of arriving at accurate estimates and fairly presenting the facts to bidders.

The cost factors to be considered by bidders are: cost of materials, cost of labor, cost of delivery of materials, cost of administering drainage contracts, cost and depreciation of necessary plant, cost of financing the contract, and probable damage claims and legal expenses. In addition to the probable contract price as thus estimated, the element of engineering and other contingent expenses and right of way or damage claims must be considered by the engineer in arriving at the total estimated cost to the owner.

Cost of Materials for Tile and Open Drains.—The principal materials entering into the construction of tile drains are tile, gravel and cement for concrete work, grates, sewer pipe, corrugated pipe, tile Y's and sewer pipe T's. No material is permanently placed in the average open drain excepting that necessary for the construction of a limited number of ditch inlets. As a rule, the cost of tile delivered at the nearest railroad station for points within the state of manufacture is fixed by the published price list of tile companies. The costs will be materially increased in cases where long-distance shipments are necessary. Discounts are seldom made by tile plants for any consideration except cash payments excepting when trade wars occur between competing plants, a possibility which is not to be safely considered in estimating costs.

The general prices for standard glazed clay tile, cement tile, tile Y's and T's, sewer pipe, sewer pipe Y's and T's, grates and corrugated pipe are listed in Table VII, together with other information of convenience to drainage engineers. These prices are applicable to the central western states and are subject to slight fluctuations because of variations in the cost of labor and demand for tile. At the present time the quotations upon cement tile are approximately the same as for clay for the smaller and considerably cheaper for the larger sizes. However, the standard of manufacture of cement tile is constantly tending toward a better product, and it is problematical as to what the difference in cost will finally be between properly manufactured tile of the two materials. As the engineer's estimate often precedes the installation of the work for periods of several years, it is a difficult matter to forecast accurately tile costs. However, allowances may be made for a general downward or upward trend of prices. It is an evident fact that tile production increases during wet periods when drainage is most extensively practiced, with a consequent tendency to overproduction during the succeeding drier years. These periods or cycles of wet or dry years occur at fairly regular intervals, and by an investigation of this tendency an engineer may forecast the general condition of the market with some degree of accuracy. The contractor's bid is compiled at a time closely preceding the actual purchase of the tile bill, and there is consequently less danger of changes in prevailing prices. The engineer's estimate should itemize the probable cost of tile, other materials, labor, etc., in order that contractors may compare the various units in relation to their cost at the time of estimating and the time of bidding, and make proper allowances and comparisons.

TABLE IX—PRICE FOR TRENCHING, LAYING OF TILE AND BACKFILLING PER 100-FOOT STATION.

Size of Tile	3-Ft. Deep	4-Ft. Deep	5-Ft. Deep	6-Ft. Deep	7-Ft. Deep	8-Ft. Deep
4, 5 and 6 in.	$2.70	$3.80	$5.45	$ 7.75	$ 9.35	$12.00
7 and 8 in.	3.30	4.70	6.35	8.65	10.55	13.60
10 in.	3.90	5.60	7.85	10.70	13.55	16.60
12 in.	4.20	6.15	8.70	11.75	14.75	18.75

TABLE X—CONVERSIONS OF FEET TO RODS.

Feet	Rods	Feet	Rods	Feet	Rods	Feet	Rods	Feet	Rods
1	.06	155	9.38	345	20.91	570	34.54	950	57.57
2	.12	160	9.69	350	21.21	580	35.15	960	58.18
3	.18	165	10.00	355	21.51	590	35.76	970	58.78
4	.24	170	10.30	360	21.82	600	36.36	980	59.39
5	.30	175	10.60	365	22.12	610	36.96	990	60.00
6	.36	180	10.90	370	22.42	620	37.57	1000	60.60
7	.42	185	11.20	375	22.73	630	38.18	1100	66.66
8	.49	190	11.51	380	23.03	640	38.78	1200	72.73
9	.55	195	11.81	385	23.33	650	39.39	1300	78.79
10	.61	200	12.12	390	23.64	660	40.00	1400	84.85
15	.91	205	12.42	395	23.94	670	40.60	1500	90.91
20	1.22	210	12.72	400	24.24	680	41.21	1600	96.97
25	1.52	215	13.02	405	24.54	690	41.82	1700	103.03
30	1.82	220	13.33	410	24.84	700	42.42	1800	109.09
35	2.12	225	13.63	415	25.15	710	43.02	1900	115.15
40	2.43	230	13.94	420	25.45	720	43.63	2000	121.21
45	2.73	235	14.24	425	25.75	730	44.24	2500	151.52
50	3.03	240	14.54	430	26.06	740	44.84	3000	181.82
55	3.33	245	14.85	435	26.36	750	45.45	3500	212.12
60	3.64	250	15.15	440	26.66	760	46.06	4000	242.42
65	3.94	255	15.45	445	26.97	770	46.66	4500	272.72
70	4.24	260	15.76	450	27.27	780	47.27	5000	303.03
75	4.54	265	16.06	455	27.57	790	47.88	5500	333.33
80	4.85	270	16.36	460	27.88	800	48.48	6000	363.63
85	5.15	275	16.67	465	28.18	810	49.08	6500	393.93
90	5.46	280	16.97	470	28.48	820	49.69	7000	424.24
95	5.76	285	17.27	475	28.79	830	50.30	7500	454.54
100	6.06	290	17.58	480	29.09	840	50.90	8000	484.85
105	6.36	295	17.88	485	29.39	850	51.51	8500	515.15
110	6.66	300	18.18	490	29.70	860	52.12	9000	545.45
115	6.96	305	18.48	495	30.00	870	52.72	9500	575.76
120	7.27	310	18.78	500	30.30	880	53.33	10000	606.06
125	7.57	315	19.09	510	30.90	890	53.94	10500	636.36
130	7.87	320	19.39	520	31.51	900	54.54	11000	666.66
135	8.17	325	19.69	530	32.12	910	55.14	11500	696.97
140	8.48	330	20.00	540	32.72	920	55.74	12000	727.27
145	8.78	335	20.30	550	33.33	930	56.35	12500	757.58
150	9.08	340	20.60	560	33.94	940	56.96	13000	787.88

The amount of concrete work necessary usually constitutes a small percentage of the contract cost, and may be estimated with sufficient accuracy at $8 to $10 per cubic yard. In cases where larger quantities of concrete are used, the cost of gravel, cement, forms and other necessary items should be definitely computed from local prices and estimates made accordingly.

Cost of Labor for Tile Drains.—While the foregoing material cost items may be estimated with reasonable exactness, especially by bidders, the cost of labor does not admit of such accurate approximation. The rates of wages often fluctuate as much as 30 to 40 per cent upward or downward during the time intervening between the preparation of the estimate and the process of construction. To the contractor operating on a small capital margin such changes are serious. In many cases the original contractor attempts to insure his profit by tentatively sub-letting all labor before submitting the bid. This arrangement results satisfactorily as long as the sub-contractor is prospering, but the sub-contractor usually operates with little surplus capital, and in case of unforeseen losses must either abandon the work or receive additional support from the original contractor. In all instances of this nature—and they are far from exceptional—the contracting party or his bondsmen must ultimately sustain the losses.

The cost of trenching, laying of tile and back filling may be estimated by the lineal foot or rod or per cubic yard of excavation, the price varying according to depth and other influencing factors; but whatever the system used, the rate of wages and condition of soil and weather are governing considerations. Drainage contractors have generally been forced to gamble upon the nature of the soil and file bids in accordance with the restrictions of competition, and as a result often bears destructive losses or receives unreasonable profits. Common business justice should require that soil surveys be made and recorded for the investigation of bidders. Such a procedure would tend to attract the better class of contractors and discourage the inexperienced and incompetent plungers from attempting work which they would be unable to execute properly. The slight increase in first cost would be more than compensated for by the advantages accruing from the intelligent prosecution and completion of the work.

Cost of Trenching.—Contractors generally estimate the cost of trenching by the lineal rod or station of 100 ft., the rate per unit of distance being increased as the depth increases. Also estimates are sometimes based upon the yardages to be excavated, as is more customary for sewer trenches. The latter method proves the more convenient and practicable, as by the use of a yardage table the total yardages may be readily computed and comparisons are more readily made in relation to wage rates. Yardages for trenches of given widths and average depths may be taken from Table VIII. The given top widths are those used in practice for average trenches. For trenches in stable soils the trenches are narrowed towards the base, thus resulting in a less number of yards excavated than is given in the table, as the computations are based upon trenches with vertical sides. On the contrary, loose, wet soils will result in the caving of the trench banks and will require the removal of excess yardages or the cutting of vertical sides and the installation of sheeting to support the earth pressure. Hence the given yardages may be applied to all trenches and varying costs per cubic yard assigned for different soil conditions and different wage rates. An analysis of a large number of actual (Iowa) contract prices for trenching, laying of tile and back filling has demonstrated that contractors as a rule have estimated the total cost of this work, including the contractors' profits, on a basis equivalent to an average rate of 40 cents per cubic yard for depths of 3 to 12 ft. for the sizes of tile included below the heavy line in Table VIII, at a wage rate of $2.50 per day for common labor without board and $3.50 to $4.00 per day for skilled tile layers and foremen. Contracts in individual cases have been let at rates corresponding to 30 cents per cubic yard at the minimum to 70 cents per cubic yard at the maximum, these variable rates depending more upon the assumed soil and weather conditions and upon competition than upon the wage rate, as the wage rate is fairly constant for the period upon which these averages have been based. Table IX gives the average cost of the same items for 100-ft. sections for the sizes included above the heavy line in Table VIII for given depths and prices per lineal rod. As many tilers, especially for small farm drains, figure their work by the lineal rod, and as engineers' measurements are in feet, a table of reductions from feet to rods is given, Table X. Statistics compiled by contracting firms would be helpful to engineers and valuable particularly to the contracting profession, and more such data should in the common interest of the profession be prepared and published.

TABLE XI—CONTRACT PRICES FOR DITCHES OF DIFFERENT YARDAGES.

Yardages	Average Coal Haul	Contract Cost per Cu. Yd.
64,154	4 miles	$0.15
75,000	6 miles	0.12
80,000	....	0.12
92,000	4 miles	0.11
112,182	5 miles	0.10
141,741	2 miles	0.09
195,000	....	0.085
202,277	4 miles	0.075
362,000	....	0.07
800,000	....	0.065

TABLE XII.

Excavation Table. *Side Slopes, 1 to 1.*

3-Foot Bottom.

Depth	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
2′	37.0	39.7	42.4	45.2	48.0	50.9	53.9	57.0	60.1	63.4
3′	66.7	70.0	73.5	77.0	80.6	84.3	88.0	91.8	95.7	99.7
4′	103.7	107.8	112.0	116.3	120.6	125.0	129.5	134.0	138.7	143.4
5′	148.1	153.0	157.9	162.9	168.0	173.1	178.4	183.7	189.0	194.6
6′	200.0	205.6	211.3	217.0	222.8	228.7	234.7	240.7	246.8	253.0
7′	259.3	265.6	272.0	278.5	285.0	291.7	298.4	305.2	312.0	318.9
8′	325.9	333.0	340.2	347.4	354.7	362.0	369.5	377.0	384.6	392.3
9′	400.0	407.8	415.7	423.7	431.7	439.8	448.0	456.5	464.6	473.0
10′	481.5	490.0	498.7	507.4	516.2	525.0	533.9	542.9	552.0	561.2

4-Foot Bottom.

Depth	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3′	77.8	81.5	85.3	89.2	93.2	97.2	101.3	105.5	109.8	114.1
4′	118.5	123.0	127.6	132.2	136.9	141.7	146.5	151.5	156.4	161.5
5′	166.7	171.9	177.2	182.6	188.0	193.5	198.9	204.8	210.5	216.3
6′	222.2	228.2	234.2	240.3	246.5	252.8	259.1	265.5	272.0	278.6
7′	285.2	291.8	298.7	305.5	312.4	319.4	326.5	333.7	340.9	348.2
8′	355.5	363.0	370.5	378.1	385.8	393.5	401.3	409.2	417.2	425.2
9′	433.3	441.5	449.8	458.1	466.5	475.0	483.6	492.2	500.9	509.7
10′	518.5	527.4	536.4	545.5	554.7	563.9	573.2	582.6	592.0	601.5
11′	611.1	620.8	630.5	640.3	650.2	660.2	670.2	680.3	690.5	700.8
12′	711.1	721.5	732.0	742.6	753.2	763.9	774.7	785.5	796.4	807.4
13′	818.5	829.7	840.9	852.2	863.6	875.0	886.5	898.1	909.8	921.5
14′	933.3	945.2	957.2	969.2	981.3	993.5	1005.8	1018.1	1030.5	1043.0
15′	1055.5	1068.2	1080.9	1093.7	1106.5	1119.4	1132.4	1145.5	1158.7	1171.9
16′	1185.2	1198.6	1212.0	1225.5	1239.1	1252.8	1266.5	1280.3	1294.2	1308.2

6-Foot Bottom.

Depth	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3′	100.0	104.5	109.0	113.7	118.4	123.1	128.0	132.9	137.9	143.0
4′	148.1	153.4	158.7	164.0	169.5	175.0	180.6	186.3	192.0	197.8
5′	203.7	209.7	215.7	221.8	228.0	234.3	240.6	247.0	253.5	260.0
6′	266.6	273.4	280.1	287.0	293.9	300.9	308.0	315.1	322.4	329.7
7′	337.0	344.4	352.0	359.6	367.3	375.0	382.8	390.7	398.7	406.7
8′	414.8	423.0	431.3	439.6	448.0	456.5	465.0	473.7	482.4	491.1
9′	500.0	508.9	517.9	527.0	536.1	545.4	554.7	564.0	573.5	583.0
10′	592.6	602.3	612.0	621.8	631.7	641.7	651.7	661.8	672.0	682.3
11′	692.6	703.0	713.5	724.0	734.7	745.4	756.1	767.0	777.9	788.9
12′	800.0	811.1	822.4	833.7	845.0	856.5	868.0	879.6	891.3	903.0
13′	914.8	926.7	938.7	950.7	962.8	975.0	987.3	999.6	1012.0	1024.5
14′	1037.0	1049.7	1062.4	1075.1	1088.0	1100.9	1114.0	1127.0	1140.1	1153.4
15′	1167.6	1180.0	1193.4	1207.0	1220.6	1234.3	1248.0	1261.8	1275.7	1289.7
16′	1303.7	1317.8	1332.0	1346.3	1360.6	1375.0	1389.5	1404.0	1418.7	1433.4
17′	1448.2	1463.0	1477.9	1492.9	1508.0	1523.2	1538.4	1553.7	1569.0	1584.5
18′	1600.0	1615.6	1631.3	1647.0	1662.8	1678.7	1694.7	1710.7	1726.8	1743.0

TABLE XII—Continued

Excavation Table. *Side Slopes, 1 to 1.*

8-Foot Bottom.

Depth	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3′	122.1	127.4	132.7	138.1	143.6	149.1	154.7	160.3	166.1	171.9
4′	177.8	183.7	189.8	195.9	202.1	208.3	214.7	221.1	227.6	234.1
5′	240.7	247.4	254.2	261.1	268.0	275.0	282.1	289.2	296.4	303.7
6′	311.1	318.6	326.1	333.7	341.3	349.1	356.9	364.8	372.7	380.8
7′	388.9	397.1	405.3	413.7	422.1	430.6	439.1	447.7	455.7	465.2
8′	474.1	483.0	492.0	501.1	510.2	519.4	528.7	538.1	547.6	557.1
9′	566.7	576.3	586.1	595.9	605.8	615.7	625.8	635.9	646.1	656.3
10′	666.7	677.1	687.6	698.1	708.7	719.4	734.2	741.1	752.0	763.0
11′	774.1	785.2	796.3	807.7	819.1	830.6	842.1	853.7	865.3	877.1
12′	888.9	900.8	912.7	924.8	936.9	949.1	961.3	973.7	986.1	998.6
13′	1011.1	1023.7	1036.4	1049.2	1062.1	1075.0	1088.0	1101.1	1114.2	1127.4
14′	1140.7	1154.1	1167.6	1181.1	1194.7	1208.3	1222.1	1235.9	1249.8	1263.7
15′	1277.8	1291.9	1306.1	1320.3	1334.7	1349.1	1363.6	1378.1	1392.7	1407.4
16′	1422.2	1437.1	1452.0	1467.0	1482.1	1497.2	1512.4	1527.7	1543.1	1558.6
17′	1574.1	1589.7	1605.3	1621.1	1636.9	1652.8	1668.7	1684.8	1700.9	1717.1
18′	1733.3	1749.7	1766.1	1782.6	1799.1	1815.7	1832.4	1849.2	1866.1	1883.0

10-Foot Bottom.

Depth	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3′	144.4	150.4	156.4	162.6	168.7	175.0	181.3	187.7	194.2	200.8
4′	207.4	214.1	220.9	227.7	234.7	241.7	248.7	255.9	263.1	270.4
5′	277.8	285.2	292.7	300.3	308.0	315.7	323.6	331.4	339.4	347.4
6′	355.6	363.7	372.0	380.3	388.7	397.2	405.8	414.4	423.1	431.9
7′	440.7	449.7	458.7	467.7	476.9	486.1	495.4	504.8	514.2	523.7
8′	533.3	543.0	552.7	562.6	572.4	582.4	592.4	602.6	612.7	623.0
9′	633.3	643.7	654.2	664.8	675.4	686.1	696.9	707.7	718.7	729.7
10′	740.7	751.9	763.1	774.4	785.8	797.2	808.7	820.3	832.0	843.7
11′	855.5	867.4	879.4	891.4	903.5	915.7	928.0	940.3	952.7	965.2
12′	977.7	990.4	1003.1	1015.9	1028.7	1041.7	1054.7	1067.7	1080.9	1094.1
13′	1107.4	1120.8	1134.2	1147.7	1161.3	1175.0	1188.7	1202.5	1216.4	1230.4
14′	1244.4	1258.6	1272.7	1287.0	1301.3	1315.7	1330.2	1344.8	1359.4	1374.1
15	1388.9	1403.7	1418.7	1433.7	1448.7	1463.9	1479.1	1494.4	1509.8	1525.2
16′	1540.7	1556.3	1572.0	1587.7	1603.6	1619.4	1635.4	1651.4	1667.6	1683.7
17′	1700.0	1716.3	1732.7	1749.2	1765.8	1782.4	1799.1	1815.9	1832.7	1849.7
18′	1866.7	1883.7	1900.9	1918.1	1935.4	1952.8	1970.2	1987.7	2005.3	2023.0
19′	2040.7	2058.6	2076.4	2094.4	2112.4	2130.6	2148.7	2167.0	2185.3	2203.7
20′	2222.2	2240.8	2259.4	2278.1	2296.9	2315.7	2334.7	2353.7	2372.7	2391.9

12-Foot Bottom.

Depth	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3′	166.7	173.4	180.2	187.0	193.9	200.9	209.0	215.2	222.4	229.7
4′	237.0	244.5	252.0	259.6	267.3	275.0	282.8	290.7	298.7	306.7
5′	314.8	323.0	331.3	339.6	348.0	356.0	365.0	373.7	382.4	391.2
6′	400.0	408.9	417.9	427.0	436.2	445.4	454.7	464.0	473.5	483.0
7′	492.6	502.3	512.0	521.8	531.7	541.7	551.7	561.8	572.0	582.3
8′	592.6	603.0	613.5	624.0	634.7	645.4	656.2	667.0	677.9	688.9
9′	700.0	711.1	722.4	733.7	745.0	756.5	768.0	779.6	791.3	803.0
10′	814.8	826.7	838.7	850.7	862.8	875.0	887.3	899.6	912.0	924.5
11′	937.0	949.7	962.4	975.1	988.0	1000.9	1013.9	1027.0	1040.1	1053.4
12′	1066.7	1080.0	1093.5	1107.0	1120.6	1134.3	1148.0	1161.8	1175.7	1189.7
13′	1203.7	1217.8	1232.0	1246.3	1260.6	1275.0	1289.5	1304.0	1318.7	1333.4
14′	1348.1	1363.0	1377.9	1392.9	1408.0	1423.1	1438.4	1453.7	1469.0	1484.5
15′	1500.0	1515.6	1531.3	1547.0	1562.8	1578.7	1594.7	1610.7	1626.8	1643.0
16′	1659.3	1675.6	1692.0	1708.5	1725.0	1741.7	1758.4	1775.1	1792.0	1808.9
17′	1825.9	1843.0	1860.2	1877.4	1894.7	1912.0	1929.5	1947.0	1964.6	1982.3
18′	2000.0	2017.8	2035.7	2053.7	2071.7	2089.8	2108.0	2126.3	2144.6	2163.0
19′	2181.5	2200.0	2218.7	2237.4	2256.1	2275.0	2293.9	2312.9	2332.0	2351.1
20′	2370.4	2389.7	2409.0	2428.5	2448.0	2467.6	2487.3	2507.0	2526.8	2546.7

TABLE XII—Continued

Excavation Table.

Side Slopes, 1 to 1.

14-Foot Bottom.

Depth	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
6′	444.4	454.1	463.9	473.7	483.6	493.5	503.6	513.7	523.9	534.1
7′	544.4	554.8	565.4	575.9	586.5	597.2	608.0	618.9	629.8	640.8
8′	651.9	663.0	674.2	685.5	696.9	708.3	719.8	731.4	743.1	754.9
9′	766.7	778.6	790.5	802.6	814.7	826.9	839.1	851.4	863.9	876.3
10′	888.9	901.5	914.2	927.0	939.9	952.8	965.8	978.9	992.0	1005.2
11′	1018.5	1031.9	1045.3	1058.9	1072.4	1086.1	1099.9	1113.7	1127.6	1141.5
12′	1155.6	1169.7	1183.9	1198.1	1212.4	1226.9	1241.3	1255.9	1270.5	1285.2
13′	1300.0	1314.9	1329.8	1344.8	1359.9	1375.0	1390.2	1405.5	1420.9	1436.3
14′	1451.9	1467.4	1483.1	1498.9	1514.7	1530.6	1546.5	1562.6	1578.7	1594.9
15′	1611.1	1627.4	1643.9	1660.3	1676.9	1693.5	1710.2	1727.0	1743.9	1760.8
16′	1777.8	1794.9	1812.0	1829.2	1846.5	1863.9	1881.3	1898.9	1916.4	1934.1
17′	1951.9	1969.7	1987.6	2005.5	2023.6	2041.7	2059.9	2078.1	2096.5	2114.9
18′	2133.3	2151.9	2170.5	2189.2	2208.0	2226.9	2245.8	2264.8	2283.9	2303.0
19′	2322.2	2341.5	2360.9	2380.3	2399.9	2419.4	2439.1	2458.9	2478.7	2498.6
20′	2518.5	2538.6	2558.7	2578.9	2599.1	2619.4	2639.9	2660.3	2680.9	2701.5

16-Foot Bottom.

Depth	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
8′	711.1	723.0	735.0	747.0	759.1	771.3	783.6	795.9	808.3	820.8
9′	833.3	846.0	858.7	871.4	884.3	897.2	910.2	923.3	936.4	949.7
10′	963.0	976.3	989.8	1003.3	1016.9	1030.6	1044.3	1058.1	1072.0	1085.9
11′	1100.0	1114.1	1128.3	1142.6	1156.9	1171.3	1185.8	1200.4	1215.0	1229.7
12′	1244.5	1259.3	1274.3	1289.2	1304.3	1319.5	1334.7	1350.0	1365.3	1380.8
13′	1396.3	1411.9	1427.6	1443.3	1459.1	1475.0	1490.9	1507.0	1523.1	1539.3
14′	1555.6	1571.8	1588.3	1604.8	1621.4	1638.0	1654.7	1671.5	1688.3	1705.3
15′	1722.2	1739.3	1756.5	1773.7	1791.0	1808.3	1825.8	1843.3	1860.9	1878.6
16′	1896.3	1914.1	1932.0	1949.9	1968.0	1986.1	2004.3	2022.6	2040.9	2059.3
17′	2077.8	2096.4	2115.0	2133.7	2152.5	2171.3	2190.3	2209.2	2228.3	2247.5
18′	2266.6	2286.0	2305.3	2324.8	2344.3	2363.9	2383.6	2403.3	2423.1	2443.0
19′	2462.9	2483.0	2503.1	2523.3	2543.6	2563.9	2584.3	2604.8	2625.4	2646.0
20′	2666.7	2687.5	2708.3	2729.3	2750.2	2771.3	2792.5	2813.7	2835.0	2856.3

18-Foot Bottom.

Depth	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
8′	770.4	783.0	795.7	808.5	821.3	834.3	847.3	860.3	873.5	886.7
9′	900.0	913.4	926.8	940.3	953.9	967.6	981.3	995.1	1009.0	1023.0
10′	1037.0	1051.1	1065.4	1079.6	1094.0	1108.4	1122.8	1137.3	1152.0	1166.7
11′	1181.5	1196.3	1211.3	1226.3	1241.4	1256.5	1271.7	1287.0	1302.4	1317.9
12′	1333.3	1348.9	1364.7	1380.4	1396.2	1412.1	1428.0	1444.0	1460.1	1476.3
13′	1492.6	1509.0	1525.4	1541.8	1558.4	1575.0	1591.7	1608.5	1625.4	1642.3
14′	1659.3	1676.3	1693.5	1710.7	1728.0	1745.4	1762.9	1780.4	1798.0	1815.6
15′	1833.3	1851.2	1869.1	1887.0	1905.1	1923.2	1941.4	1959.6	1977.9	1996.4
16′	2014.8	2033.4	2052.0	2070.7	2089.5	2108.4	2127.3	2146.3	2165.4	2184.5
17′	2203.7	2223.1	2242.5	2261.9	2281.4	2301.0	2320.7	2340.4	2360.2	2380.1
18′	2400.0	2420.1	2440.2	2460.3	2480.5	2500.9	2521.4	2541.8	2562.3	2583.0
19′	2603.6	2624.5	2645.4	2666.3	2687.3	2708.4	2729.5	2750.7	2772.0	2793.4
20′	2814.9	2836.4	2858.0	2879.6	2901.3	2923.1	2945.0	2966.9	2989.0	3011.2

20-Foot Bottom.

Depth	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
10′	1111.1	1126.0	1140.9	1155.9	1171.0	1186.1	1201.3	1216.6	1232 0	1247.4
11′	1263.0	1278.5	1294.2	1310.0	1325.8	1341.7	1357.6	1373.7	1389.8	1406.0
12	1422.2	1438.6	1455.0	1471.4	1488.0	1504.6	1521.3	1538.1	1555.0	1571.9
13′	1588.9	1606.0	1623.1	1640.3	1657.6	1675.0	1692.4	1710.0	1727.6	1745.2
14′	1763.0	1780.7	1798.7	1816.6	1834.7	1852.8	1871.0	1889.2	1907.6	1926.0
15′	1944.4	1963.0	1981.6	2000.3	2019.1	2038.0	2056.9	2075.9	2095.0	2114.1
16′	2133.3	2152.6	2172.0	2191.4	2211.0	2230.6	2250.2	2270.0	2289.8	2309.7
17′	2329.6	2349.7	2369.8	2390.0	2410.2	2430.6	2451.0	2471.4	2492.0	2512.6
18′	2533.3	2554.1	2575.0	2595.9	2616.9	2638.0	2659.1	2680.3	2701.6	2723.0
19′	2744.4	2766.0	2787.6	2809.2	2831.0	2852.8	2874.7	2896.6	2918.7	2940.8
20′	2963.0	2985.2	3007.6	3030.0	3052.4	3075.0	3097.6	3120.3	3143.1	3166.0

Cost of Delivery of Materials.—Under the division of cost of delivery of materials will be considered only the cost of transporting all requisite materials from the nearest railroad station to the line of work. Because of the small amount of gravel, cement and forms necessary, the average cost per cubic yard for concrete work may be considered as including all items connected with concrete work. The cost of delivery of tile forms a large percentage of any tile drain cost because of the tonnage involved. This work is usually best accomplished by the contractor sub-letting the hauling to local parties at so much per ton, an arrangement which may also prove unsatisfactory in case the sub-contractor fails to clear any profits. A more businesslike method would be to withhold a percentage to insure the completion of the hauling, but as a rule available teamsters in country towns generally refuse to contract the work otherwise than upon a full cash payment basis. They are also often able to dictate their own terms and fix their own standards of compliance, because of their scarcity.

Conditions favorable to low ton mile rates are hard roads, level gradients, stable right of way along which the tile are to be distributed, such a length of haul that a definite number of round trips may be made in one day, and dry weather during the time of hauling. It is seldom, however, that many of these conditions exist in a given case. The average country roads are not surfaced with hard material, and become heavy and impassable during wet weather, and it often occurs, at such times, that the delivery of tile cannot be readily delayed because of the economy of hauling direct from the car and the demand for tile at the line of ditch. At times when tile companies are sufficiently stocked to be able to make shipments as desired, the delivery of tile may be more closely conformed to road conditions. The necessity of traversing one or more steep hills on the route or of distributing the tile upon wet, swampy locations, conditions which require lighter loads or the occasional doubling of teams, tend materially to increase the cost of hauling. To estimate the cost of hauling per ton most accurately the number of tons per load that may be successfully hauled and the number of trips possible per team per day should be estimated for the probable road conditions, and the resulting daily tonnage divided into the rate of wages customary for a man and team per day gives the approximate cost

TABLE XIII.

For Slopes of 1¼ to 1 Add Following Yardages to 1 to 1 Yardages.

Depth	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3′	8.3	8.9	9.5	10.1	10.7	11.4	12.0	12.7	13.3	14.1
4′	14.8	15.6	16.3	17.1	17.9	18.7	19.6	20.4	21.4	22.3
5′	23.2	24.1	25.0	26.0	27.0	28.1	29.2	30.1	31.2	32.3
6′	33.4	34.4	35.6	36.8	37.9	39.1	40.3	41.6	42.8	44.1
7′	45.4	46.8	48.0	49.4	50.7	52.1	53.5	54.9	56.3	57.8
8′	59.3	60.7	62.3	63.8	65.3	66.9	68.5	70.1	71.7	73.4
9′	75.0	76.7	78.3	80.1	81.8	83.6	85.3	87.1	88.9	90.7
10′	92.6	94.5	96.4	98.2	100.1	102.1	104.0	106.0	108.0	110.0
11′	112.0	114.1	116.2	118.3	120.4	122.5	124.6	126.8	128.9	131.0
12′	133.3	135.6	137.8	140.0	142.4	144.7	147.0	149.4	151.7	154.1
13′	156.5	158.9	161.3	163.8	166.2	168.7	171.2	173.7	176.3	178.9
14′	181.5	184.1	186.7	189.3	192.0	194.7	197.3	200.0	202.8	205.6
15′	208.4	211.2	214.0	216.8	219.6	222.4	225.3	228.2	231.1	234.0
16′	237.0	240.0	243.0	246.0	249.0	252.1	255.2	258.3	261.4	264.5
17′	267.6	270.7	273.9	277.1	280.3	283.6	286.9	290.2	293.5	296.8
18′	300.1	303.4	306.8	310.2	313.6	317.0	320.4	323.8	327.3	330.8
19′	334.3	337.8	341.4	345.0	348.6	352.2	355.8	359.4	363.0	366.7
20′	370.4	374.1	377.8	381.5	385.3	389.1	392.9	396.7	400.5	404.4

For Slopes of 1½ to 1 Add Yardages to 1 to 1 Yardages.

Depth	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3′	16.6	17.8	19.0	20.2	21.4	22.7	24.0	25.4	26.7	28.2
4′	29.6	31.2	32.6	34.2	35.8	37.4	39.2	40.9	42.7	44.5
5′	46.3	48.2	50.1	52.0	54.0	56.0	58.1	60.1	62.3	64.5
6′	66.7	68.9	71.2	73.5	75.9	78.3	80.7	83.1	85.6	88.1
7′	90.7	93.4	96.0	98.7	101.5	104.2	107.0	109.8	112.7	115.6
8′	118.6	121.5	124.5	127.6	130.6	133.8	137.0	140.2	143.4	146.7
9′	150.0	153.4	156.7	160.2	163.6	167.1	170.6	174.2	177.8	181.5
10′	185.2	189.0	192.7	196.5	200.3	204.2	208.1	212.0	216.0	220.0
11′	224.1	228.1	232.3	236.5	240.7	244.9	249.2	253.5	257.9	262.2
12′	266.7	271.1	275.6	280.1	284.7	289.3	294.0	298.7	303.5	308.2
13′	313.0	317.8	322.7	327.6	332.5	337.5	342.5	347.5	352.6	357.8
14′	363.0	368.2	373.4	378.7	384.1	389.5	394.9	400.3	405.7	411.2
15′	416.7	422.3	427.9	433.5	439.2	444.9	450.6	456.4	462.3	468.2
16′	474.1	480.0	486.0	492.0	498.1	504.2	510.4	516.6	522.8	529.0
17′	535.2	541.5	547.9	554.3	560.7	567.1	573.6	580.1	586.7	593.3
18′	600.0	606.7	613.4	620.1	626.8	633.6	640.5	647.4	654.3	661.3
19′	668.3	675.4	682.6	689.8	697.0	704.2	711.5	718.7	726.0	733.4
20′	740.8	748.2	755.6	763.1	770.7	778.3	785.9	793.5	801.2	808.9

per ton. At the rate of $5.00 per day for a man and team, the cost of hauling averages from 50 to 80 cts. per ton mile for the first mile and 20 cts. to 35 cts. per ton mile for each additional mile. Over favorable earth roads one team will move a 2 to 2½ ton load as readily as two teams could move a 1 ton load under the most unfavorable conditions, which indicates the difficulty of tabulating average ton mile costs and illustrates the risk of a contractor basing his bid upon the possibility of favorable roads. The cost of transporting dredging machinery and hauling coal in general would be subject to the same road restrictions applicable to the hauling of tile. The costs of dredging outfits, their transportation, assembling and tearing down, cost of hauling coal, and the cost of all other items connected with open drains not being accurately available, a list of contract prices per yard for drains of varying yardages is given in Table XI. This table illustrates approximately the total cost per cubic yard considered necessary to cover all costs for contracts of the given yardages and Iowa soil conditions.

Yardage Computations for Open Drains.—As the yardage involved is the basis for all computations in relation to open drains, a table showing the yardages for 100 ft. sections for varying depths for given base widths and slopes is very convenient to drainage engineers and contractors. Table XII gives the yardages for open ditches of side slopes of 1 to 1 and different base widths and depths. As practically all open drains are in level agricultural territory, the yardages are computed on the basis of level ground surfaces. In case of side slopes of 1¼ to 1 or 1½ to 1, the yardages may be totaled for all sections on the assumption that the side slopes are 1 to 1 and the difference in yards between 1 to 1 sections and sections of the given slope listed from Table XIII and the total of additional cubic yards added to the total yards for sections of 1 to 1 ditches of similar depths.

The yardage of ditches of any base width and any slopes may be computed from Table XIV by the use of the formula

$$\text{Cubic Yards} = A\left(\frac{B}{20}\right) + C \times S$$

where A = Sum of yards in the rectangular sections of a ditch of 20-ft. base and similar depths.
B = Base width of ditch.
C = Sum of yards in the triangular sections of a 1 to 1 sloped ditch of similar depths.
S = Rate of horizontal to vertical slope.

TABLE XIV.

YARDAGE IN THE 2 TRIANGULAR SECS. OF 1 TO 1 SLOPED DITCHES FOR ALL BASES.

Depth	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3′	33.3	35.6	37.9	40.3	42.8	45.4	48.0	50.7	53.5	56.5
4′	59.3	62.3	65.3	68.5	71.7	75.0	78.4	81.8	85.3	88.9
5′	92.6	96.3	100.1	104.0	108.0	112.0	116.1	120.3	124.6	128.9
6′	133.3	137.8	142.4	147.0	151.7	156.5	161.3	166.3	171.3	176.3
7′	181.5	186.7	192.0	197.4	202.8	208.3	213.9	219.6	225.3	231.1
8′	237.0	243.0	249.0	255.1	261.3	267.6	273.9	280.3	286.8	293.4
9′	300.0	306.7	313.5	320.3	327.3	334.3	341.3	348.5	355.7	363.0
10′	370.4	377.8	385.3	392.9	400.6	408.3	416.1	424.0	432.0	440.0
11′	448.1	456.3	464.6	472.9	481.3	489.8	498.4	507.0	515.7	524.5
12′	533.3	542.3	551.3	560.3	569.5	578.7	588.0	597.4	606.8	616.3
13′	625.9	635.6	645.3	655.1	665.0	675.0	685.0	695.1	705.3	715.6
14′	725.9	736.3	746.8	757.4	768.0	778.7	789.5	800.3	811.3	822.3
15′	833.3	844.5	855.7	867.0	878.4	889.8	901.3	912.9	924.6	936.3
16′	948.1	960.0	972.0	984.0	996.1	1008.3	1020.6	1032.9	1045.3	1057.8
17′	1070.4	1083.0	1095.7	1108.5	1121.3	1134.3	1147.3	1160.3	1173.5	1186.7
18′	1200.0	1213.4	1226.8	1240.3	1253.9	1267.6	1281.3	1295.1	1309.0	1323.0
19′	1337.0	1351.1	1365.3	1379.6	1393.9	1408.3	1422.8	1437.4	1452.0	1466.7
20′	1481.5	1496.3	1511.3	1526.3	1541.3	1556.5	1571.7	1587.0	1602.4	1617.8

YARDAGES IN THE RECTANGULAR SECS. OF 20′ BASE DITCHES.

Depth	0	.1	.2	.3	.4	.5	.6	.7	.8	.9
3′	222.2	229.6	237.0	244.4	251.9	259.3	266.7	274.1	281.5	288.9
4′	296.3	303.7	311.1	318.5	325.9	333.3	340.7	348.1	355.5	362.9
5′	370.4	377.8	385.2	392.6	400.0	407.4	414.8	422.2	429.6	437.0
6′	444.4	451.8	459.2	466.7	474.1	481.5	488.9	496.3	503.7	511.1
7′	518.5	525.9	533.3	540.7	548.1	555.6	563.0	570.4	577.8	585.2
8′	592.6	600.0	607.4	614.8	622.2	629.6	637.0	644.4	651.8	659.2
9′	666.7	674.1	681.5	688.9	696.3	703.7	711.1	718.5	725.9	733.3
10′	740.7	748.1	755.5	762.9	770.3	777.8	785.2	792.6	800.0	807.4
11′	814.8	822.2	829.6	837.0	844.4	851.8	859.3	866.7	874.1	881.5
12′	888.9	896.3	903.7	911.1	918.5	925.9	933.3	940.7	948.1	955.5
13′	963.0	970.4	977.8	985.2	992.6	1000.0	1007.4	1014.8	1022.2	1029.6
14′	1037.0	1044.4	1051.8	1059.2	1066.6	1074.1	1081.5	1088.9	1096.3	1103.7
15′	1111.1	1118.5	1125.9	1133.3	1140.7	1148.1	1155.6	1163.0	1170.4	1177.8
16′	1185.2	1192.6	1200.0	1207.4	1214.8	1222.2	1229.6	1237.0	1244.4	1251.9
17′	1259.3	1266.7	1274.1	1281.5	1288.9	1296.3	1303.7	1311.1	1318.5	1325.9
18′	1333.3	1340.7	1348.1	1355.6	1363.0	1370.4	1377.8	1385.2	1392.6	1400.0
19′	1407.4	1414.8	1422.2	1429.6	1437.0	1444.4	1451.8	1459.3	1466.7	1474.1
20′	1481.5	1488.9	1496.3	1503.7	1511.1	1518.5	1525.9	1533.3	1540.7	1548.1

Compiled by J. L. Parsons, Civil Engineer, Humboldt, Iowa.

By the use of this formula computations may be made for any ditch in level ground very rapidly compared to the laborious process of computing end areas for each 100-ft. section.

There are certain geometrical relations existing between the cross-sectional areas and yardages of different sized ditches which are useful in making comparisons, computing yardages and preparing yardage tables, which will be stated in order in formulas and rules:

(1) The average width of any ditch equals the sum of the base width and the depth multiplied by the rate of horizontal slope, or

$$W = B + D S,$$

which must be true, because

$$W = \frac{2 (D S) + 2 B}{2} = B + D S.$$

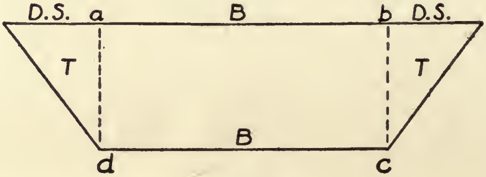


Fig. 26A

(2) Therefore, since the average width $= B + D S$, the yardage of a 100-ft. section of any ditch may be computed from the formula

$$Y = \frac{D (B + D S) \times 100}{27}$$

(3) The yardage of the rectangular portions of 100-ft. sections—*abcd*—increases or decreases in proportion to the base widths for ditches of similar depth, as the only variable factor of such sections is the width; similarly the yardages of these sections are independent of the rate of side slopes and are the same for all ditches of similar base widths and depths.

(4) The yardages in the triangular portions of 100-ft. sections may be computed from the formula

$$Y = \frac{D (D S) \times 100}{27}$$

as the two triangular sections T and T' may always be combined in a rectangular form one side of which equals the depth of the ditch and one side the depth multiplied by the rate of horizontal slope, and therefore the yardages of ditches of similar depths and different side slopes will vary as the variation of horizontal slope. This is true because the only variations in this rectangle are occasioned by change in the slope, which change proportionately governs the length of the horizontal side of the improvised rectangle. Also the yardages of the triangular sections can in no way be affected by changes in base widths, and yardages computed for these sections for given depths and slopes are constant for all base widths.

(5) Based on these relations, the formula

$$Y = A\left(\frac{B}{20}\right) + CS$$

was developed for use in connection with Table XIV.

Cost of Administration of Contracts.—The cost of administering contracts, or overhead expenses, often amounts to a very nominal percentage, as many of the smaller tile contracts are taken by local contractors who fulfill the duties of manager, foreman and office man, while at the same time personally accomplishing the most expensive portion of the work—the laying of the tile. In the case of the contracting companies operating on a larger scale, a central office must be maintained and the work closely supervised, and the expense thus incurred must be pro-rated over all the work under construction. These conditions tend to demoralize the contracting business from the standpoint of the general contractor and operate against the formation and healthy development of tile drainage contracting companies. For the larger contracts aggregating a total cost of $15,000 and upward the individual local contractor ceases to be a competitor because of his inability to finance them and to compete in the item of management with the more scientifically organized companies. These conditions may or may not be the best for the final interests of owners, but as they so generally exist they must be recognized by engineers and contractors in the preparation of estimates and bids.

Before bidding upon dredge work a contractor must be of sufficient financial stability to at least own a dredging oufit and in addition furnish the necessary certified check and bonds, which limits the construction of open drains to a lesser number of competitors. Notwithstanding, the tendency has been for a large number of individuals to enter the field and scale bids in order to secure work, often attempting to slight the work as much as possible to enable them to pay out, the consequence being unsatisfactory relations and work, legal suits, and sometimes the failure of the contractor concerned, the greatest losers being the land owners, who must eventually pay excessively for a satisfactory ditch. In view of these facts, boards of supervisors, engineers, attorneys and others upon whom devolves the letting of contracts should inquire more into the ability of bidders to prosecute and complete the work satisfactorily, and less stress be placed upon low bids. Drainage notices usually reserve the right to let the work to the lowest responsible bidder, but the instances where the lowest bids have been rejected have been very rare, although in many cases their rejection would have been amply justified.

Plant Expenses.—Plant expenses for tile drains are reduced to a minimum, as practically all items of cost consist principally of labor and of materials entering permanently into the construction of the drain. It is sometimes economical or necessary to erect shacks or tents in which to house and board the laborers, in which instances the cost of such structures should be estimated. Also when tile work is prosecuted during the winter months it is necessary to provide shelter and heat near the location of the work, which is readily transported as the work progresses. In ordinary warm weather the principal materials and tools necessary are tiling spades, shovels, pick ax, devices for grading the bottom of the ditch, maul for driving curbing, sheet-iron sand box, crowbar, sand pump, derrick, trench braces, curbing, and sometimes tools for blasting rocks. In cold weather or in cases where extreme hardpan is encountered more picks are necessary and all tools wear more rapidly. The amount, cost and life of the tools and materials vary widely between different contracts, but no estimate is complete without a liberal allowance being made to provide for these items. A very false economy of attempting tile work without providing curbing, trench braces, sand box and sand pump is commonly practiced, and far greater losses are sustained than would result from the provision and use of them. Therefore their cost enters into the total cost of tile trenching work either directly if provided or indirectly through higher labor costs if not provided. The plant necessary for open drains consists of the necessary machinery and housing cabins, and forms a larger percentage of the total cost. As the total cost of dredge work has been referred to as being pro-rated over the yardage, it will not be discussed further.

Cost of Financing Contracts.—The cost of financing drainage contracts constitutes the defeat of many would-be contractors. These novices in this phase of public works contracting, who are usually of limited financial resources, often estimate all other items of cost with reasonable accuracy, but neglect the consideration of the cost of providing the necessary capital. There are various points in this connection to be relatively considered by a prospective bidder, which will be noted in the order of their occurrence during the progress of a contract. First, a certified check must be furnished of a stipulated percentage of the bid, which is usually a small item of expense, as banks require an interest-bearing note to secure them against loss, the interest being legitimate returns for borrowed credit. The bidder may deposit the cash in lieu of a certified check if he possesses sufficient funds, but in this case he loses the possible interest on his money until the contract is executed and the money returned. If for any reason the successful bidder is unable to secure the necessary bonds, he is generally required to forfeit the security deposit, a fact which should impress upon all bidders the importance of ascertaining definitely their ability to furnish bonds before filing bids. Second, the successful bidder must furnish bonds of a stipulated amount to insure the completion of the contract. Personal bonds, if securable, may or may not cost the contractor anything; but a percentage of approximately 1 per cent is charged by bond companies, the premium to be paid annually; and a very pertinent point to be remembered in this connection is that bond companies do not furnish bonds unless the contractor is able to prove himself safe financially.

Funds are also necessary to the prosecution of any contract, and the relative cost of providing them depends upon the bank account of the contractor, the methods of payment and duration of the contract. In the exceptional case where the contractor commands sufficient funds to finance the entire project, warrants or other forms of paper he might receive in payment would usually bear as high a rate of interest as his funds would draw in the form of bank deposits, and the only loss or expense would be the loss of the interest upon the percentage of payments withheld until the completion of the contract. To the contractor who does not command working capital the method of payment is a vital matter. If payments are to be in cash only approximately the difference between monthly payments and actual cost need be provided for. The necessity of providing these funds may often be delayed by buying the tile and other materials on 60 or 90 days' time, although this financial advantage would be counterbalanced in case these materials could be purchased at a cheaper rate for cash payments. Also if payments to tile or other companies are delayed beyond the specified time of payment, overdue accounts are charged a specified rate of interest, which operates similarly to the borrowing of the same funds at a similar rate of interest as regards the resultant cost. But if the method of payment is by drainage warrants or similar paper bearing a low rate of interest, which is not payable at a specified time, the contractor is burdened with the additional expense of their disposal. In many communities where such paper is abundant it is a difficult matter to dispose of it upon reasonable terms, and in all cases the buyer discounts them a sufficient percentage to insure him 7 to 8 per cent upon his investment. Many contractors secure work without properly estimating the cost of disposal of such warrants, with consequent disastrous losses or reduction of profits.

Contractors' Damage Losses.—During the prosecution of drainage contracts there is considerable danger of stock falling into ditches, with resulting claims for damages by the owners, and some allowance must be made in the contractor's estimate for such accidents. Also a contractor should avail himself of enough legal advice to insure business methods. Although neither of these items is of much importance in the average contract, it occasionally occurs that one or the other or both constitute a large percentage of the cost, and it is good business for the contractor to protect his drains and business relations so as to avoid future complications and losses, and this protection requires the expenditure of funds, and thus merits consideration in this connection.

District Legal Expenses.—Legal expenses should be incurred by the engineer and owners upon all drainage organizations to a sufficient extent to insure that all methods of procedure are according to law, which item of cost is ordinarily not prominent as a factor of the total cost to the owners. In cases of appeals to the courts and extended litigations, legal expenses may constitute a surprising percentage, which fact emphasizes the necessity of proceeding with such projects in accordance with law and good engineering practice.

Damage Claims for Open Drains.—Damage claims or right of way expenses are only of importance in the case of open drains. The specific method of awarding damages to the owners through whose land the open drains extend may vary for different states, but the elements of damages are the same for all cases, and consist of the actual value of the land appropriated for ditch purposes, the cost of fencing the ditch on both sides if fencing is necessary or required, the cost of necessary bridges across the open drain for convenience in farming operations and the reduction in the value of the farm because of resulting appearance and inconvenience because of the construction of the ditch. In estimating the value of land appropriated for open drains, the actual value of the particular strip of land in question may be very little, but it must be remembered that the value of any part of a farm is fixed in the minds of buyers partly by the future possibilities of draining it and the prospective buyer would naturally not be informed as to the particular location of a future ditch. Hence the value of any particular acre taken should be measured by its value in its natural state plus any additional value resulting from the possibility of securing drainage, provided the ditch or a tile drain were located on some closely adjacent land. In cases where open drains are so located that small irregular shaped corners are separated from the remainder of a farm, which are of such sizes and shapes that their value for agricultural purposes will not justify the construction of bridges to make them accessible, the measure of damages to these tracts should rightfully include the value of the lands so separated. The inclusion of the value of such lands in damage allowances should eliminate the necessity of allowances for bridges in these instances. Three-wire fencing is ordinarily sufficient for open drains and costs complete about 50 cents per rod. Four-foot woven wire fencing with 5-in. posts spaced 8 rods apart will average approximately 75 cents per rod. Bridges of sufficient strength for farm purposes may be constructed at an approximate cost of $5.00 per lineal foot. The cost of repairing and replacing bridges after a reasonable length of time is not generally considered. The allowing of liberal damages for bridges and fences to property owners would be more justifiable if owners more generally applied the damages so received for the intended purpose instead of neglecting these items and allowing stock to damage the drains by continually crossing them. A method which results in a more satisfactory maintenance of ditches is for the district organization to construct the bridges and fences and maintain them as a part of the district expense.

The deterioration of farm values because of the construction of open drains is often given considerable prominence by juries because of the natural aversion of many people to the presence of open ditches and their accompanying waste banks upon lands belonging to them. Little weight should be given to this item except in unusual cases, as open drains are ordinarily constructed upon lands which in their natural state are crossed by watercourses which are more unsightly at times and which render the different portions of the farm more inaccessible than is possible to be caused by the construction of an open drain properly bridged. Instances occasionally arise where the measure of damages for the last reason should be larger as the construction of an open ditch through land which in its natural state was not crossed by the natural watercourse, but which is traversed by the drain for the purpose of shortening the length or for similar reasons.

Damages to Railway Companies.—The method of awarding of damages to railway companies because of open or closed drains crossing their rights-of-way is generally so prescribed by state drainage laws that there are few questions to be determined by damage commissions. The general rule laid down in many states is that railway companies shall be allowed as damages only the cost of material for and the construction of the drains across the rights-of-way. The cost of bridging the ditches, damages to existing bridges and delays to traffic are held to be inherent public liabilities of railway companies which cannot be charged against drainage districts. The basis for this theory is concisely set forth in the text of the decision of the United States Supreme Court in the case of the C., B. & Q. Ry. Co. vs. Commissioners of Drainage District No. 1, Bristol Twp., Kendall Co., Ill., extracts from which are as follows:

> "When the railway company laid the foundations of its bridge in Bob Roy Creek it did so subject to the rights of the public in the use of that watercourse, and also subject to the possibility that new circumstances and future public necessities

might, in the judgment of the state, reasonably require a material change in the method used in crossing the creek by cars. It may be—and we take it to be true—that the opening under the bridge as originally constructed was sufficient to pass all the water then or now flowing through the creek. But the duty of the company, implied in law, was to maintain an opening under the bridge that would be adequate and effectual for such an increase in the volume of water as might result from lawful, reasonable regulations, established by appropriate public authority from time to time for the drainage of lands on either side of the creek. . . . The great weight of authority is, that where there is a natural watercourse, or where a highway already exists and is crossed by a railroad company under its general license to build a railroad, and without any specific grant by the legislative authority to obstruct the highway or waterway, the railway company is bound to make and keep its crossing, at its own expense, in such condition as shall meet all the reasonable requirements of the public as the changed conditions and increased use may demand. . . .

"The duty of a railroad to restore a stream or highway, which is crossed by the line of its road, is a continuing duty; and, if by the increase of population or other causes, the crossing becomes inadequate to meet the new and altered conditions of the country, it is the duty of the railroad to make such alterations as will meet the present needs of the public. . . .

"The duty of the company will end when it removes the obstructions which it has placed in the way of enlarging, deepening and widening the channel. It follows, upon principles of justice that while the expense attendant upon the removal of the present bridge and culvert and the timber and stones placed by the company in the creek, as well as the expense of the erection of any new bridge which the company may elect to construct in order to conform to the plan of the commissioners, should be borne by the railroad company, this expense attendant merely upon the removal of soil in order to enlarge, deepen and widen the channel must be borne by the District."

In some states a provision has been made in connection with the section governing the appraisal of railway damages, allowing railway companies the privilege of constructing drainage improvements across their rights of way instead of hiring the contractor to do this work with the money allowed for this purpose. The result has been that open drain contractors have been placed at the mercy of the railroads, and that they have often been forced to pay bonuses to railway companies rather than be forced to dismantle their machinery and rebuild on the opposite sides of the rights-of-way. This provision tends to increase bids and is no more just than a provision allowing each land owner a similar privilege would be. Railway companies are entitled to fair treatment, but are not entitled to a privilege of this character which has been so grossly abused. Such sections of drainage laws could, with justice to all concerned, be altered so as to provide for a right-of-way through railway property upon reasonable notice from the supervising engineer, the cost of construction across the railway property to be paid by the drainage district. The necessity of appraising railway damage claims would then be eliminated, the construction of drains would be greatly simplified and facilitated, and the costs of drains traversing one or more railroads would tend to be reduced.

Contingent Expenses.—The contingent expenses incidental to legal drainage organizations, as engineering, legal expenses, publication of notices, etc., if wisely administered, need not exceed 8 to 12 per cent of the total cost for drains costing $5,000 and upward. These expenses equal a larger percentage for the smaller districts, as many of the legal procedures required are as expensive for small drains as for the larger ones.

The item of engineering alone, including the preliminary survey, construction superintendence, and assistance in the assessment of benefits and fixing of damages, should not be less than 5 to 10 per cent of the total cost, ranging from approximately 10 per cent for $2,000 districts to 5 per cent for $25,000 districts and upward.

Responsibility of Engineers.—Drainage engineers generally escape apparent responsibility for wild and unbalanced estimates because of the facts that bidders themselves vary so radically in their bids and that prevailing prices and wage rates do change materially after estimates are prepared. These influences, however, should not excuse them from investigating all conditions affecting costs and presenting the data and estimates so completely that bidders may acquaint themselves with actual facts and conditions.

CHAPTER VII

THE PREPARATION AND ENFORCEMENT OF DRAINAGE SPECIFICATIONS

Object and Scope of Specifications.—As in other engineering enterprises, specifications supplement the plans in enumerating in detail all requirements as to the nature and quality of necessary materials, the standards to which all completed work must conform, the mutual obligations of contractor and owner, and all other matters incident to the successful administration and completion of the work. Also the component specification clauses are probably as variously interpreted by owners, engineers and contractors with as many resulting disagreements and lawsuits as in other lines of contract work. The controlling intention of the discussions in the preceding chapters has been to emphasize the importance of drainage engineers investigating and intelligently analyzing all influencing conditions during the prosecution of the preliminary survey and the preparation of plans in order that drainage systems may be planned and constructed according to sound designing principles, that reliable records may be permanently available, and that contractors and land owners may be definitely informed concerning the actual conditions which will be encountered during the construction and the results to be expected after construction. It is equally essential that the specifications governing the actual installation of the work be as thoroughly evolved to insure proper construction, and also be brief, concise and so simply, fairly and accurately stated that the mimimum of injustice and litigation will arise in their enforcement.

Specifications relating to legal drainage organizations only will be discussed, as such a list will necessarily include all items applicable to the smaller farm systems and organizations by contract agreements. All specification items necessary for inclusion in cases of drainage districts will be treated in the following order: (1) Each specification will be stated in its proper sequence in the language and form advocated by the author; and (2) various possible and common requirements and interpretations will be analyzed and discussed and the function of the construction engineer in the enforcement of the specifications and the discharge of his duties as judge and arbiter between the interested parties during actual construction commented upon. Specifications for tile drains and open ditches will first be considered in order followed by a discussion of the general provisions applicable to all drains.

As the subject of tile, their strengths, testing and changes in specifications will be more fully discussed in a following chapter, these questions will not be commented upon here.

Digging and Backfilling.—(Spec.) All excavation shall be in open trench and the tile shall in all cases be blinded to a depth of at least 6 inches (with earthy material) after being laid. In all backfilling a sufficient amount of the excavated or other material must be placed in and over the tile trench to leave a ridge over the trench at least 6 inches in height above the original ground level. Where the trench is located in existing open ditches, only the excavated material will be required to be replaced unless otherwise specified. At any time after one month has elapsed after the laying of the tile, the engineer may require the backfilling to be completed for that portion unless serious filling of the tile has occurred in which cases the contractor shall be allowed a reasonable length of time to repair the drain before completing the backfilling, the contractor at all times to retain legal responsibility for damages resulting from unprotected open trenches.

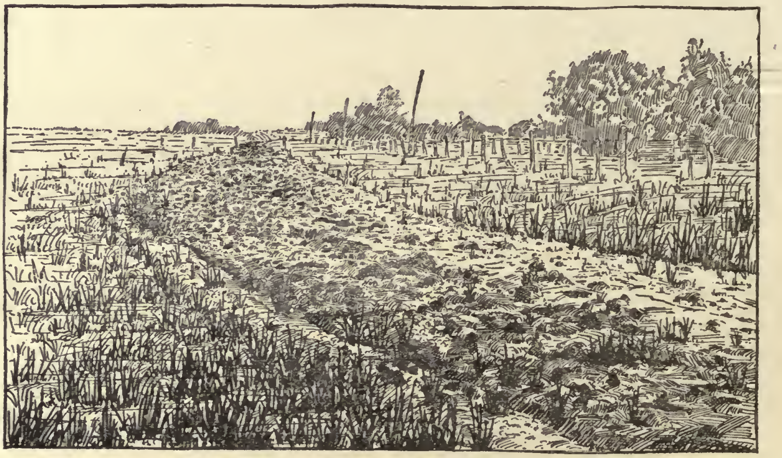


Fig. 27—View of a Tile Drain Properly Back-filled

Under this item two points are especially important: blinding of tile and backfilling of trenches. Tile should be blinded as soon as laid in all cases, as sudden rains more seriously damage uncovered tile because of the softening and displacing of the trench base resulting in uneven settling of the tile and opening of the joints. The blinding material should not be sand or other fine material which tends to flow readily through the joints when mixed with water. The backfilling should ordinarily be completed as soon as possible to protect the drain from damage and permit land owners the freer cultivation and use of their land, and some provision is advisable by which the contractor may be required to complete the backfilling within reasonable limits of time in case the conditions demand. Figure 27 presents a view of a job of backfilling properly completed, and Fig. 28 a view of a job of partially completed backfilling.

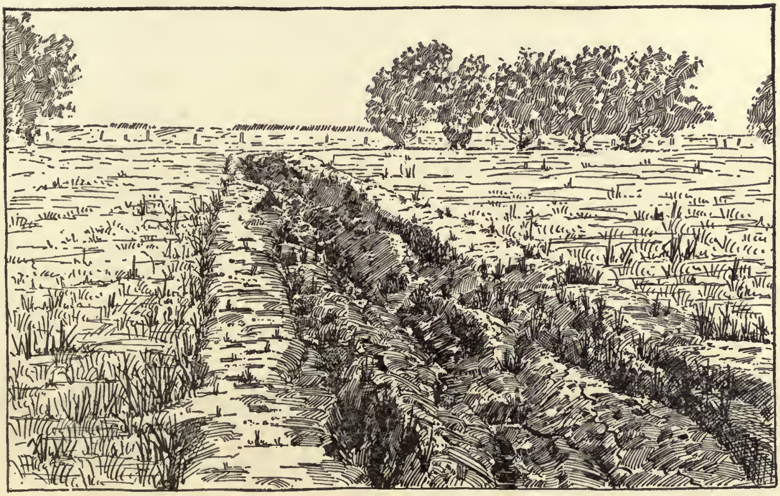


FIG. 28—View of a Tile Drain Partially Back-filled

Laying of Tile.—(Spec.) All tile shall be laid to a true line and grade and with close joints. In cases where close joints are not possible, all joints greater than ¼ inch shall be suitably patched with tile bats. The contractor will be required to adopt necessary precautions against the filling of tile, and shall remove all filling which has accumulated in the tile during the construction of the drain to depths greater than 15 per cent of the diameters of the tile, for which no extra compensation will be allowed. All profile depths will be considered as being the depths from the top of hub stakes to the bottom of trench.

In regard to methods of laying tile, specifications should in no case dictate the specific system to be used in laying tile to conformity to grade other than that some reliable method must be used to accomplish the desired results. Some workmen accomplish the best work by the use of the line method, while others are more successful with the target method. As in other specifications, the desired results should be clearly defined, the exact method of accomplishment being determined according to the individual preferences of the contractors and workmen concerned. The accuracy of the grade to which the tiles have been laid and the general condition of the joints may be tested by uncovering the tile at intervals of 10 to 25 feet, determining the elevations of the tops of the tile at these points and inspecting the joints carefully. In determining the correctness of the grade to which the tile have been laid the thickness of the tile from outside to outside must be deducted from the elevations of the tops of the tile and due consideration be given to any irregularity there may be in the shape of the tile used. In all cases the grade of the tile should be checked at as close intervals as hub stakes are set, as errors in the engineer's figures or in the setting of the lines or targets might result in inaccurate grading at the stations where errors are made which would escape detection if check readings were taken at too great intervals.

Setting and Use of Targets.—To properly enforce the specifications, an engineer and his assistants should be generally familiar with the setting and use of grade lines and targets; the tendency of tile drains to fill during construction and the methods best adapted to insure well-laid, clean drains. An engineer's position in regard to these points must necessarily be that of an adviser. Many practicing tilers are not properly skilled in the use of targets, the use of sand-boxes, curbing, and other devices to prevent caving and filling and are not properly impressed with the importance of good construction; and it is as much the duty of the engineer in such cases to tactfully suggest practicable methods as it is to demand the correction of careless work. Better final results may often be achieved by the preventive method as the cleaning of filled drains and relaying of tile are seldom effected as satisfactorily as could have been accomplished by proper workmanship in the first operation.

The common purpose of all systems of grading is the projection of a line or sight above and parallel to the proposed grade line. Measurements are then made from this parallel line at necessary points to determine the depths of trench. The determining points of this line are fixed at stations by measuring upward distances equal to the difference between the length of grade stick to be used and the depths of trench at stations. For instance, if the grade stick is 5 ft. in length and the depth of trench at a particular station is to be 3 ft., 11¾ in., the line should be set 1 ft. ¼ in. above the top of the hub at this point. The line, or targets, are most conveniently set at stations by the use of a graduated ruler or measuring device of a length of about 3 feet less than the greatest length of grade sticks used, the graduations being started at the 3-ft. mark. By extending the ruler downward in the trench and making the figures on the ruler corresponding to the depth of trench coincide with the top of the hub stake, the line or target may be set at the 5-ft., or other graduation equal to the length of the grade stick, without subtracting. This method, when used, eliminates many errors which would otherwise be made in the complicated process of subtracting inches and fractions of inches. The heights of the line above the grade line being thus determined, upright stakes are set, carrying projecting boards, or arms, at the required elevations over which a heavy cord is stretched taut from which measurements are made to determine the depths of trench. The projecting arms should in all cases be leveled by means of a carpenter's level, or a level set in the upper edges of the arms, to insure the line being at the proper height above the hubs. Another method is to drive iron or wooden stakes on each side of the trench at each station, and extend a board between them across the ditch the top edge of which is adjusted to the desired height above the hub stake. A cord is then drawn taut and measurements made as in the preceding case. In the use of the target method, the cord is dispensed with and depths between stations determined by sighting from the top of a grade stick over the boards as set in either of the above cases. Whether the tile are laid by the use of the line or target method it is evident that the tops of the grade boards should be in a straight line for uniform grades and that this line will be broken if there is a change of gradient at any station. The tile layers should in all cases be informed of the rates of gradients and the location of all changes in gradients in order that they may readily account for the irregular lining of grade boards at points of change and detect any errors which might have been made in the engineer's or tile layers computations. Also many tilers in using the target method grade the ditch and lay the tile from one station to the next in accordance with the rear grade boards and thus are liable to lay the tile in a section just in advance of a change of grade station by the preceding gradient if not aware of the point of change. Tilers should be impressed by the engineer with the importance of observing these points as serious errors in the computations are oftentimes thus detected and corrected and the necessity of expensive correction work avoided.

The filling of tile during construction usually results from one of two causes: the inflowing of slushy sand or joint clay soil through the joints or into the open end of the tile. The exclusion of fluid soils is a difficult matter of accomplishment and demands extreme care in construction to secure satisfactory results. The use of plank curbing properly braced with stringers and spreaders is indispensable in cavy soils. Too often curbing is not provided and the attempt is made to dispense with its use with the result that large masses of the

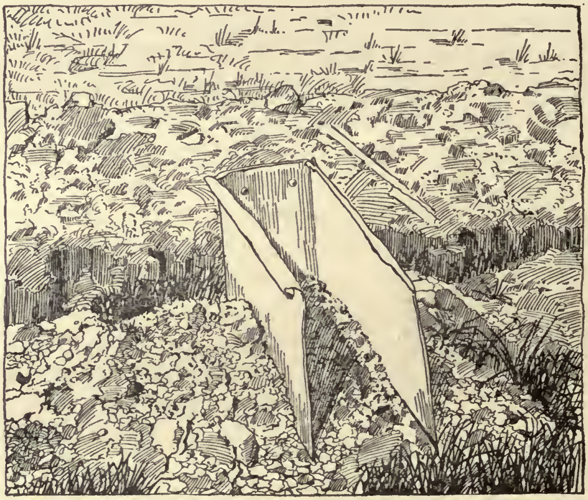


Fig. 29—Design for a Sheet Iron Sand-Box

banks cave into the trench endangering the lives of the workmen and incurring extra expense to remove the caved material. Curbing is best used in connection with a sand box, if unstable soil is encountered near the base of the trench, as tile may be laid in better condition for alignment and joints and less penetration of curbing is required. A sheet-iron sand-box adaptable for this purpose is illustrated in Fig. 29. The side and end pieces are forced into the fluid soil far enough to prevent its inflow for each tile separately, and the tile may then be laid on a compacted bed of coarse hay, tile bats or the natural soil; the joints well covered with coarse hay, tile bats or straw, stable soil packed along the sides and over the tile and the end of the tile closed with a heavy board before the removal of the box. To care for the excess water which constantly collects in front of the tile, a sheet-iron cover may be used for the end of the tile, the upper portion being perforated so as to allow the entrance of the water and the exclusion of the silt. The difficulty of the removal of the sand-box often constitutes the most serious objection to its use as ordinarily done by hand labor. This process may be greatly simplified by the casting of a heavy bar to the centers of the tops of the two side pieces and effecting their withdrawal by the extending of a heavy rope, or chain, from the bar to the block of the derrick used for lowering tile into the trench; the power being applied by the use of the windlass and pulley block.

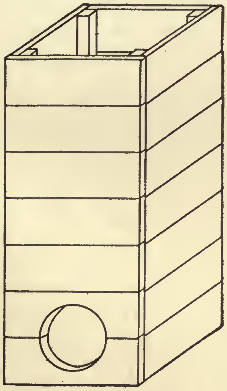


FIG. 30—Design for a Wood Box Inlet

Protection of Tile Drains from Filling.—Tile drains should also be constantly protected from the effects of rains as filling is certain to result if overflow waters are allowed to enter the unprotected end of the tile or to wash over the blinding material. Dams should be constructed in the trench at intervals to direct overflow waters into the tile during construction. If the soil is stable, the end of the tile may be protected by a perforated cover only; but if unstable, the end of the tile should be provided with some kind of an inlet each time the work is left. This may be accomplished by the placing of a sewer pipe T at the end of the tile line, and the building up of tile or sewer pipe to a level above the slush. The water will then be forced to rise behind the trench dam and enter the tile line through the inlet without an excess load of silt. The same object is accomplished by the use of a wooden box inlet similar to Fig. 30 placed over the end of the tile. There are very few cases of filled tile drains which could not have been prevented with little trouble or expense by the contractor making use of suitable preventive methods. Because of a prevalent spirit of laxity, it is a difficult matter to induce tilers to adopt these precautionary measures; but much may be accomplished by practicable, insistent and tactful advice and suggestions.

Inlets and Retaining Walls.—(Spec.) All accessories shall be constructed in accordance with the structural features shown on the accompanying plans. All cement necessary shall be of a standard brand Portland cement. All gravel necessary shall be reasonably graded from coarse to fine, and shall be free from earthy material. In the construction of inlets the sewer pipe shall be built up to a level of 9 inches below the level of the nearest adjacent low spots, the backfilling shall be thoroughly tamped in place around the vertical pipe and be allowed to settle for a period of at least one month before the placing of the concrete and the top of the concrete ring in any place shall not extend above the level of the top of the sewer bell. Notice must be given the engineer before the construction of any or all accessories in order that their construction may be inspected. Ditch inlet pipes must be placed before the ditch is excavated at their locations in such a manner that the spoil banks will be deposited regularly over them.

It is unnecessary to incorporate lengthy, detailed specifications requiring cement, sand, and other material to meet certain complicated tests which are not practicable of application for the amount of construction involved of these materials; but it is essential that such materials meet the simpler requirements and that the construction of accessories be inspected in order to insure the proper completion of all hidden parts. Many tilers seem determined to finish the tops of inlets above the level of the ground and skimp the foundations of retaining walls, practices which in cases result in more damage to a drain than their omission would cause. A few hours of instruction and inspection will usually prevent all such mistakes before considerable expenditure becomes necessary to correct them. Ditch inlet pipes may be placed successfully during construction by the ordering of the corrugated pipe in two sections, one being placed in a trench through the proposed location of the waste bank, and the remaining section connected by bolting and extended in a trench through the berm into the ditch after the dredge has passed the location of the inlet. By this method the spoil banks form levees directing the flood waters into the inlets and preventing the washing of lateral channels.

Ditch Slopes.—(Spec.) The side slopes shall be constructed on a slope of .. horizontal to .. vertical as nearly as can be accomplished by the skillful use of a floating (or dry land) dredge. It shall not be counted a fault if the top is excavated wider than required, provided the extra width does not exceed 2 ft., but both base and top widths must be equal to those specified. The base width must not exceed the specified base width more than 2 ft.

It is impracticable to draft strict slope specifications and insist upon absolute compliance during construction, as the most skillful crews cannot accomplish symmetrically perfect work with a dredge, but certain reasonable limits which are essential to the permanency of completed ditches should be fixed and enforced. When floating dredges are used, the slopes cannot be viewed until the excavation has progressed a sufficient distance to lower the water level to or near the ditch base, but as soon as this has occurred the slopes should be investigated and directions for future work issued.

Ditch Berms.—(Spec.) The berms shall be .. ft. clear in width and must be left practically free from deposits. The ditch edges of the berms shall be removed by the dipper during the construction of the ditch, and both edges of the ditch shall conform to practically straight lines.

The enforcement of the provision of clean berms and trimmed edges is very important to the maintenance of open drains. Ditch contractors will concertedly urge upon engineers the unavoidable necessity of leaving a roll of sods and earth along the ditch edges, but succeed in very successfully removing such rolls when required to do so. The laxity in regard to these rolls has been so general that contractors have naturally come to base their bids upon ditches constructed with rolls, and it is only right that the contractors be notified through the specifications as to what will be expected in this regard and not be forced to gamble upon the engineer's interpretation of "clear berms," which are often specified. The effect of heavy rolls on the ditch edges if allowed to remain must invariably be their caving into the bottom of the ditch in a short space of time, often accompanied by large sections of the banks which have become dislodged by the superimposed weight. In case a previous examination has indicated that clear berms and straight edges are not possible of attainment because of the presence of unstable soils, the specifications should require the installation of machinery capable of

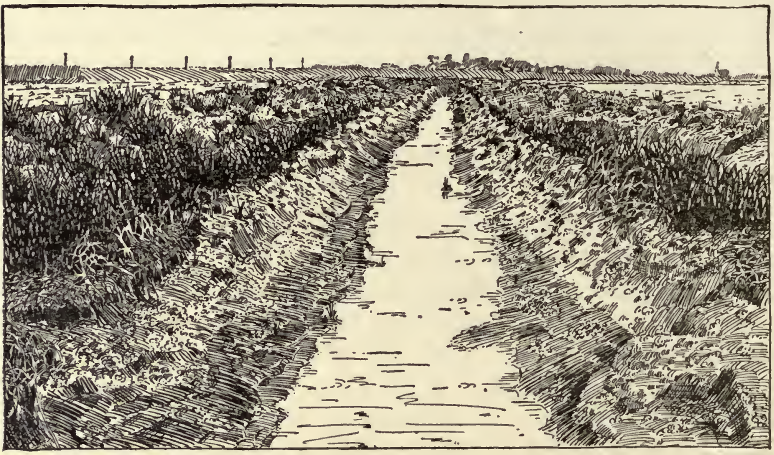


Fig. 31—View of Trimmed Ditch Edges

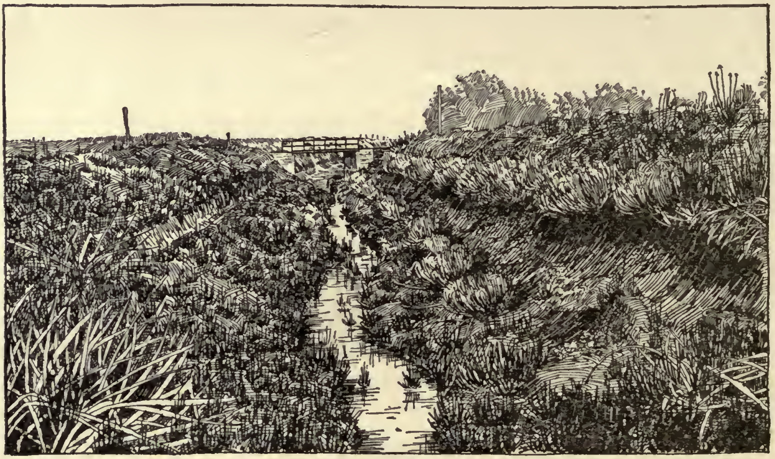


Fig. 32—View of a Ditch Edge Carrying a Roll of Sod

removing the spoil to greater distances from the ditch edges and more lenient restrictions set as to final berm conditions. Figure 31 is a view of a ditch edge with the roll properly removed, and Fig. 32 is a view of a ditch edge carrying a heavy roll of sod.

Waste Banks.—(Spec.) All waste banks shall be deposited in equal amounts on each side of the ditch in regular lines unless otherwise specified, and openings shall be left for the entrance of surface waters wherever ordered by the engineer.

Ditches are often located near public highways or old channels or similar places where it may be desirable to have all excavated material deposited to one side of the ditch. Special reference should be made to such sections and the distances affected, as contractors rightfully object to being arbitrarily compelled to carry all excavation to one side of a ditch unless duly notified in the proposal advertisements and specifications.

Yardage Computations.—(Spec.) Yardages shall be computed from the natural ground level, and no deductions will be made for old channels excepting for section .., in which section the equivalent yardage of the present channel will be deducted from the yardages as computed from the natural ground level.

This clause is necessary to correctly advise bidders and to prevent disputes during construction. There seems to be no settled rule as to the deduction of yardages which may have been already excavated by natural or artificial agencies, and a specification clause should be included to prevent confusion and injustice.

Maintenance of Ditches.—(Spec.) Ditch contractors will be held responsible for the general condition of each section of the ditch until its acceptance, the ditch being divided into sections of 2,000 ft., the acceptance of any section not to constitute a final acceptance for the payment of the withheld 20 per cent. In case any section is caused to fill or is otherwise damaged because of the failure of the contractor to complete adjoining sections within the specified time the contractor will be required to repair the damage to the satisfaction of the engineer.

Many drainage specifications require the contractor to maintain the ditch to grade until final completion and acceptance. A very usual result of this plan is the filling of the ditch above the grade, the refusal of the engineer and commissioners to accept and a legal suit instituted by the contractor to compel the payment of the retained 20 per cent or by the commissioners to compel the cleaning of the ditch, procedures which may or may not compel the owner to pay the full price for an unsatisfactory ditch or the contractor to clean the drain, but which cannot ordinarily result in benefit as regards the condition of the ditch, as the case is very exceptional where a contractor is induced or forced to return and clean up. A much more satisfactory method is for the owners to let a ditch planned sufficiently deep to allow for the estimated filling, inform contractors that all excavation will be allowed for and no extra depth required during construction, and upon such assurance of protection contractors will bid in the usual contract as cheap or cheaper than they would a shallower planned ditch, with the uncertainty of final acceptance and payment included. The final resulting ditch will also far more permanently meet the requirements which all open drains must meet.

Inspection of Open Drains.—(Spec.) The engineer in charge shall inspect the completed portions of open drains at least once a month for depths and conditions of slopes, berms and waste banks. Such inspection shall be the final inspection, and the completed portion shall be accepted or corrections required, such acceptance to be subject to the conditions set forth in the "Maintenance" and "Methods of Payment" clauses. The contractor shall be entitled to an inspection of the open drain at any time if inspection becomes necessary to allow of the backing up of the dredge for cleaning purposes before the level of the water is too low, upon proper notification of the engineer. A failure of the engineer to so inspect the ditch shall not relieve the contractor of the responsibility of exercising due precautions in excavating to the necessary depths.

The standards that should be adopted by a construction engineer in inspecting ditches will depend largely upon the plans and maintenance specifications. If the ditch is planned of the minimum required depth, the contractor should be required to excavate one to three feet of extra depth, dependent upon the fluidity of the soil and the length of time that will expire before the removal of the back water behind the dredge before the final acceptance of the drain. Many contractors willingly excavate excess yardages for self-protection, while others can be induced to do so only by a refusal to issue estimates. A failure to thus insure a ditch under such plans and specifications is certain to result in a shallow ditch, unfairness to the owners if the ditch is accepted without deepening, and unfairness to both land owners and contractors if the lines of least resistance are followed and the ditch allowed to be excavated only to the grade line and later an acceptance of the ditch refused. If the plans and specifications are so framed as to provide for excess depth excavation to allow for filling, less difficulty and friction will be experienced in enforcing the intent of the specification, as contractors can not rightfully object to excavating to the grade line indicated on the profile.

The depth of ditches behind floating dredges may be readily checked by ascertaining the elevation of the water level based upon some adjacent bench-mark and then sounding the depths by the use of a level rod, the soundings being taken from a row boat. The depths of the water deducted from the elevation of the water level will equal the elevations of the ditch base, which may be recorded opposite and compared with the required grade line elevations in the note book. If a row boat is not available, soundings may be made by the use of a weighted line attached to a fish pole, in which case the weight should be of such shape as not to readily penetrate into the loose soil in the ditch bottom. The line may be knotted at foot intervals and the decimals of a foot estimated for each sounding. Care is necessary in the application of either method to sound only to the level of the ditch base instead of penetrating the filled material which may have accumulated, as such filling will invariably settle and remain and tend rather to be reinforced with other filling than to be washed out.

Extras.—(Spec.) In case it becomes necessary during the construction of the drain to construct extra lengths of tile lines, extra accessories, or to excavate additional yardages over and above the amounts advertised, the contractor shall construct the same upon the written order of the engineer and shall be paid for such extra work at the same rate as bid for similar items or at the actual cost plus 20 per cent if no unit price has been agreed upon. The right is retained by the first party to reduce the quantities, to exclude any items or to make any changes in the dimensions or locations of the drains, provided that the total reductions shall not exceed 20 per cent of the contract price, and provided proper notice has been given the contractor before he has delivered the necessary materials for construction upon the ground, and to make deductions from the payments under the contract at the rate of unit prices agreed upon for such work.

This section is unnecessary in cases where state drainage laws govern the method of making all changes. In all cases the preliminary investigations and resultant plans should be as nearly as possible so complete and accurate that alterations in dimensions and quantities will not be necessary. But in the period between the inception and construction of drainage works conditions often arise or new data is acquired which amply justify certain changes, and some provision properly safeguarded for the protection of both owner and contractor should be included to legalize such alterations.

Sub-Letting.—(Spec.) The contractor shall not sub-let any portions of the work without the consent of the engineer in charge, and the contractor must retain all responsibility for the work done by sub-contractors. The original contractor only will be recognized in making payments.

Payments.—(Spec.) At the end of each month the engineer will issue estimates to the contractor for 80 per cent of the value of the work completed and for all accepted material delivered on the line of ditch during the preceding month, and no payments will be considered as releasing the contractor from the obligation of replacing all defective work or materials in the accomplishment or furnishing of which fraud has been practiced. Twenty per cent of all estimates will be retained by the party of the first part until the entire contract has been completed and accepted.

From the standpoint of contractors a proper innovation under this section would be a clause requiring the construction engineer to inspect and pass upon the quality and fitness of all materials before being placed, such approval to constitute final acceptance as far as the particular material is concerned. Up to the present time, as far as the author is informed, drainage specifications have either excluded a specific reference to defective work and materials or have been so broadly stated as to require the contractor to be subject to orders from the engineer to replace any or all material at any time before the acceptance of the work. The owner is certainly entitled to protection from inferior work and materials, and with equal justice the contractor is entitled to some assurance that materials have been specified according to sound engineering principles by a competent engineer, that intelligent inspection of materials will be provided for and that materials accepted for the work by the construction engineer are finally accepted unless damaged from some other causes for which the contractor is responsible.

Extensions of Time.—(Spec.) Delays caused by legal difficulties, failure of other contractors to complete work, unfavorable weather conditions, or any other cause, shall not constitute a charge for damage against the owner, but the contractor may be allowed an extension of time by the engineer to compensate for reasonable delays. In cases where the commencement of a contract depends upon the completion of other work, which work is not completed at the specified time, the time of commencement and time of completion shall be extended a length of time equal to the delay.

Under this section it would be best to specify in particular the reasons which will be considered as causes for delay and about the extent of time they will be allowed to complete the work for each cause, and if unusual weather conditions are not to be considered as a sufficient cause on account of desired early completion, this should be so stated. The inclusion of penalty clauses is of doubtful value in drainage specifications because of the general legal interpretation that liquidated damages cannot exceed the measure of actual damages incurred by the delay, for which the contractor will be liable anyway because of non-fulfillment of contract according to the terms of agreement.

Definitions.—(Spec.) The party of the first part, or owner, shall be considered as the land owners or the legal organization representing a number of land owners for whom the work is being prosecuted. The party of the second part, or contractor, shall be considered as the person, partnership or corporation to whom the contract has been duly awarded. The engineer shall be considered as the civil engineer appointed by the proper authorities to supervise the work of construction, which engineer shall have possession of all plans, reports and specifications, shall supervise all work, issue all orders and directions as to the prosecution of the work according to plans and specifications, and who shall be sole arbiter in case of disputes between owner and contractor.

Protection of Work.—(Spec.) The contractor shall at all times guard his work and shall save harmless the owner from any damages arising from his failure to do so. Where open or tile ditches cross public highways, the contractor shall protect the traveling public by means of suitable lights and barricades, and in the case of tile drains the contractor shall refill such portions as soon as the tile are laid.

Foremen.—(Spec.) Orders given to the contractor's foremen by the engineer shall be considered the same as given to the contractor in person.

Prosecution of Work.—(Spec.) If the contractor fails or refuses to comply with the specifications or to prosecute the work at the rate necessary to complete the work at the time set forth in the proposal, the owners shall have the right to declare the contract null and void, and re-let the unfinished portion of the work, the original contractor and his bondsmen to be liable for any excess cost made necessary through his failure to complete the work, and also to be liable to the owner for any damages arising from his failure to complete the contract at the specified time.

Summary.—These specifications and discussions have been intended more for the purpose of indicating the necessary items that should be included in drainage specifications and their formulation so that they may be fairly and intelligently applied during construction than to fit special cases or meet legal requirements as to phraseology. There are special conditions in every locality which require notice and treatment in the specifications, all of which should be analyzed according to local needs, and legal advice should be secured in the preparation of all important specifications. Even though specifications are minutely and carefully prepared and all plans are drawn in accurate detail, it is a common experience for drainage engineers to meet with such ignorance or carelessness on the part of the contractors or their foremen that the plans and specifications are often entirely ignored or only partially applied. In all such cases the engineer should see that the parties in charge are provided with copies of plans and specifications, and diligently supervise the work when it is first commenced, and educate the workmen to the necessity of conformance to plans and specifications. This course, if the plans and specifications are right, as they should be, insures more permanently satisfactory work, and incidentally protects the contractor against himself by preventing him from furnishing defective materials and accomplishing unsatisfactory work that must eventually be replaced or rebuilt.

CHAPTER VIII

THE DIVISION OF COSTS OF DRAINAGE SYSTEMS

The Relation of Assessments to Design and Costs.—The construction of drainage works is a form of improvement which, if properly planned, involves the expenditure of large amounts of funds, and which must generally be financed and paid for by the parties at interest or their representatives. The drainage engineer may plan the system with scientific accuracy and in the process will often be importuned persistently by owners to plan smaller or larger tile, to substitute very large tile for open drains, and to extend or shorten the drains; but oftentimes he is the only party who is cognizant of the great differences in the cost radical features of design will involve. Eventually the cost item becomes vital when the engineer with other commissioners has concluded the division of costs among the interested owners. And at that time becomes particularly apparent the importance of planning and managing drains so accurately and consistently that all operations will admit of reasonable explanations before the legal officers concerned, and, if necessary, the courts, even though the owners themselves may not in all particulars be satisfied.

Systems of Assessments and Classifications.—The method of division of costs does not admit of uniform systematizing for all drainage enterprises because of the various and complicated features incidental to each case. However, as in the application of any business scheme, the fundamental principles are of more importance than the system, and the most complete system cannot be successfully applied without a comprehension of principles. Therefore in this discussion the underlying principles will be dwelt upon at length and the suggested system be stated with little comment. The basic principle to which all benefit assessments must directly or indirectly be referred is the elevation of the land in question in relation to the proposed drain. The natural or inherent advantage which relieves the owner of land of the necessity of expending proportionately large amounts of money for drainage is sufficient elevation to result in either natural drainage or easily and cheaply installed artificial drainage. It is this natural advantage which enhances the value of land, and any benefit assessment which unduly encroaches upon this advantage furnished by nature is confiscation. Therefore a benefit commission should not attempt to apportion costs before acquiring a complete record of the elevation of every pond and low spot in the watershed and sufficient elevations upon the adjoining slopes to indicate the lands possessing natural outlets independently of the drain under consideration.

With this data at hand, a commission should personally inspect each separate tract in the district, noting the classification of the land, its distance away from the outlet, its elevation, and other pertinent information. This information may be conveniently entered upon the section sheets heretofore referred to. It is not enough to pass along one side or through a 40-acre tract, as appearances and areas are deceiving when viewed from a distance; hence it is necessary to view all parts of a forty or smaller area carefully. Lands are customarily classed as swamp, wet, low and dry lands. Swamp lands may be defined as lands lying in a submerged condition in wet seasons and not usable for any agricultural purposes; wet lands, as those lying above the swamp water level, which are unfit for any purposes except for light crops of hay or second-grade pasturing, and which require thorough tiling before being of any agricultural value; low lands, as those intervening between the wet and high lands which are not low enough to be valueless for cropping purposes, and still require a limited amount of drainage to insure annual crop production; and dry lands, as those which are of sufficient elevation and porosity of soil to render them self-draining and tillable at all times. Under this system of division considerable high lands may be classed as swamp, wet or low, but as this method is usually more readily comprehended by commissioners it seems most practicable to classify according to the term dry instead of high. Proper consideration may be given to the natural elevation of the lands later during the office work. It is best in thus classifying lands to recognize interior watershed divides and make separate classifications for the portions of tracts draining in different directions toward the main drain, especially if branches are extended into the tributary draws as parts of the district.

Obstacles to Classifications.—It should be the object of the commissioners to classify the lands upon an equitable basis, proper allowances being made for misleading appearances. Justice may be more nearly accomplished if part or all of the commissioners have been somewhat familiar with the lands during wet seasons in case the field work is prosecuted during a dry period. A more essential consideration is that at least a majority of the commission has had broad experience in this class of work, this being particularly true of the engineer member. In all cases the qualified commission may estimate with fair accuracy the condition of the lands in wet times from the general appearances of crops, weeds, etc., and classifications may be made accordingly. Common causes of confusion to commissioners are the appearance of well-farmed lands as compared to weedy, run-down lands, and of tiled as compared with untiled farms. To as nearly as possible insure uniformity due allowance must be made for these extremes and classifications be made such as to allow for them, the poorly and well farmed tracts being classed according to their probable condition, providing each were farmed with the same degree of care.

In regard to the tiled and untiled tracts the imagination is taxed considerably in order to separate the tiled tract into the classifications which would be applicable were the farms untiled or in a state of nature. Much opposition and misunderstanding often arise from the application of this rule, but in no other way can comparative justice be attained than by placing all lands upon an equal basis as nearly as may be. To illustrate: two adjacent forties may naturally possess identical opportunities of drainage and be originally in about the same condition of wetness; one forty has been tiled as thoroughly as possible with the available outlet, the other one remains in its natural state. Their natural advantages are similar and they should be treated similarly, which can only be accomplished by classing them upon some similar basis, and credit, if credit is due, be given because of any natural elevation.

Assessment Factors.—The various influencing factors upon just assessments which merit consideration are: the location of the tract with reference to the main drain; the location of the tract with reference to the outlet of the main drain; the comparative elevation of the tract; the relation of classifications to assessments; the design of the main as affecting the tract; and the comparison of the costs of the drain in and the requirements of different sections of the watersheds and the fertility of the soil. In many cases districts have been assessed as units, the cost of the main and all branches totaled and spread over the affected lands as a whole, more emphasis being placed upon the elevation and character of the lands and the actual increase in the value of the lands because of the improvement than upon the costs of particular portions of the drain. But the actual ratio of benefits to costs, even though the cost should exceed the benefits, is not a question for the benefit commission to consider. This question has been necessarily considered in the establishment of the district. The sole duty of the commission must be to assess the costs to the benefited tracts in the same proportion as they are benefited relative to each other. Also different sub-watersheds of drainage districts which are served by branch drains are usually as independent of each other as though they were organized as separate districts, and in justice they should be assessed as separate districts. Because of these facts a benefit commission should be governed in their divisions by costs as well as actual benefits and should be acquainted with the contract prices or estimated costs of the entire district and of each separate portion of the system serving some portion of the district. The logical method, then, must be to assess the cost of the main drain to all the lands in the watershed receiving benefits and the cost of each branch to its tributary lands separately, thus requiring each unit of land, or watershed subdivision, to pay only the actual costs incurred for outlet privileges and the installation of the branch. Therefore any reference to main drains may be considered as applicable to any drain, even though it is tributary to some other drain.

Location of Lands with Reference to the Main Drain.—The location of any particular tract of land with reference to the main greatly affects the benefits received. If traversed by the drain, the benefits of direct drainage by one single line of drain is at once acquired, and in addition the outlet for laterals is furnished so conveniently that expensive collecting sub-mains are not so essential. The exact location of the drain across the tract bears upon the degree of benefits, as the direct benefit of a drain extending through the comparatively higher land of a tract is not so great as would result were it intersecting a wetter portion of the tract. The farther distant from a main that a tract is located, the less the immediate benefits, even though the main is necessary for outlet purposes, as considerable funds must be expended to attain the benefits immediately accruing to the more adjacent lands. For comparative purposes estimates may be made of the direct drainage value by computing the cost of an 8-in. or 10-in. tile line of the same length as that of the main upon the tract and the cost of securing similar benefits by the installation of sub-mains if the tract is situated at a distance from the main. Such estimates are of value as means of comparing the resulting benefits between similar acreages in different locations. The question of distance of lands from mains must always be dependent upon other considerations, previously mentioned, and is only the influencing factor when other conditions are such as to render the natural advantages of the tract otherwise equal.

Location of Lands with Reference to the Main Outlet.—Prominence is sometimes given to the location of lands in relation to the outlet of the main drain on the theory that the upper owner is dependent upon the owners below for outlet privileges, and should purchase capacity throughout the length of the drain in addition to providing the more immediate necessary drainage. A serious difficulty of this plan, if applied regardless of other considerations, is that there is practically no limit that may be set upon the final cost to owners of land in the upper portions of a district on the process of the formation and extensions of districts, which sometimes extend to the improvement of large river channels. The more general and more reasonable view is that lands similarly located along a watercourse are mutually concerned in the cost of the main drain, other things being equal, as the upper lands cannot be successfully drained without an outlet, and the lower lands cannot be drained without the installation of a drain of sufficient size to care for all waters collecting from lands above. And even though a drain of such required size be located upon the lower lands, full benefit cannot be enjoyed by them because of the absence of the regulatory action which would result from the construction of the complete main and branches. Because of this interdependence of adjoining lands along natural drainage courses it is difficult to ascribe any especial advantage to particular lands for this reason alone.

However, lands may be situated opposite the watercourse in such a location that credit should be given. It is more noticeably common in the larger districts to find sub-watersheds extending laterally from the main watercourse, often paralleling it or extending at an angle from it for long distances, which are of sufficient elevation to insure them from overflow from the lands lying above the junction of the lateral and main draws, and which may or may not require the improvement of the main watercourse for outlet purposes. Whatever the system of spreading assessments used, sufficient final adjustments should be made to insure that such lands do not bear too great a proportion. This may be ascertained by computing the lump sum that seems just for such a watershed to pay and comparing this with the total sum of the assessments upon the lands in question. This lump sum can only be approximated by computing the cost of the main from its outlet up to the point of outlet of these lands and estimating the proportion of this cost that should be paid by them. The farther towards the source that a branch watershed connects with the main watercourse, the greater will be the share of the main proportioned to it for this reason.

The above rule is just and safe of application in all cases where subsidiary watersheds are not subject to overflow at times when floods occur in the main watercourse. In the latter case the overflowed lands come in the same class as do the lands adjoining the watercourse in that they are not independent of the water above the outlet and are naturally interested in the care of the flood waters both above and below the junction point. The degree to which they are affected is determined by their elevation and the consequent damage from occasional overflows or prevention of underdrainage.

In estimating the proportion of main costs to be apportioned to sub-watersheds the actual cost of the main should not always govern, but more consideration should be given to the probable cost of a drain which would suffice for outlet purposes for the land in question, or the probable cost of a drainage district organized primarily to secure an outlet for these lands only. In such estimates it must be remembered that damage claims might necessarily be paid for such an imaginary district constructed and proper allowances made. It is not argued that such sub-watersheds should pay all costs that would be incurred in case a separate district were thus organized, but such comparisons are suggested as a means of arriving at and measuring the natural disadvantages and resulting benefit of any tract. Although the factor of outlet distance under discussion is especially applicable to the larger districts, it merits just as serious consideration in the case of all tracts, whether aggregating forty acres or thousands of acres.

Elevation of Lands.—As previously suggested, the comparative elevation of a tract of land is a governing factor in all assessment considerations. The courts generally decide assessment cases upon the theory that a tract possessing sufficient elevation to render it independent of the proposed drain for a drainage outlet is not subject to assessment. The interpretations of this rule are varied and difficult. Although a tract lying in the watershed may be successfully drained upon adjacent lands, it may be so surrounded by swampy, wet lands as to be partially inaccessible for agricultural purposes, which tract is without question directly benefited to a limited degree by the reclamation of adjacent swamp lands. However, if it is so situated that it is practically accessible and also readily drained, it is no more directly benefited than similar lands situated outside the bounds of the watershed. The only benefit in such cases results from increased value of the land because of the general improvement of the community, which constitutes indirect benefits generally to be held inoperative. Although benefits assessed to lands of this character should in all cases be nominal in amount, it seems just that all lands lying in the watershed of a district should be subject to some assessment for outlet privileges.

In the determination of the question of the independence of particular lands, the elevation of the land should not absolutely govern, as the outlet may be into stagnant ponds or overflowed swales, which might not constitute reasonably natural or legal watercourses. The liability of such lands for damages to the owners of the lower lands under the state drainage laws, were a drainage district organized expressly for them, should therefore influence the amount of benefits, as this damage liability is removed or assumed in the organization of the larger district. Although the fact that lands are classed as swampy is usually evidence of benefits, the measure of benefits of this class of land must largely depend upon the elevation of the swamp lands. The factor of depth largely influences the cost of both open and tile drains, and those low spots which require the greatest depths for outlet purposes are certainly most benefited because of the greater expense incurred to overcome this natural disadvantage. Not only must greater depth be provided for such areas, but greater capacity should also be designed for the very lowest points because of their tendency to serve as catch-basins for the overflow from surrounding lands, which collected water, possessing no natural means of escape, must be removed by artificial means. The excess depths required for certain tracts may be readily computed and the cost estimated, which item of additional cost is certainly not an item of benefit to the adjacent higher elevation swamps.

Relation of Classifications to Assessments.—In regard to the classifications of lands, emphasis should be placed upon the natural state of the land as influencing the assessments, but classifications do not necessarily constitute the most controlling factor. Benefits must always be largely measured by the cost of reclaiming the land and the resulting increase in the value of the land because of the installation of the drain. As the value of the lands in their natural state is greater for dry lands than for wet, its benefits are consequently less. For these reasons the swamp lands, being the lowest, of the least original value, and requiring the greatest expenditure for outlets, bear the greatest benefits, wet, low and dry lands bearing less in order. Thus classifications are important as indications of benefit when considered in connection with the other considerations already enumerated. Assessments per acre upon swamp lands should be the same for areas similarly located and of similar elevations. The classification of ''swamp'' should have little effect upon the assessment in case the swamp is of sufficient elevation to allow of successful drainage, in which case swamp lands deserve all the natural credit due dry lands. Swamp lands referred to in this connection are those swamp lands situated to one side of the course of the drain and not traversed by it. Wet lands are usually considered as receiving less benefit because of the facts that their natural value is greater and their elevation such that deep trench work and large drains are not so necessary to furnish them outlets. Wet lands so situated as to require deep drains should be assessed similarly to swamp lands. Low and dry lands in order should bear less ratios of the costs for similar reasons. Classifications of lands are popularly considered as being the principal influencing factor in the determination of benefit assessments. This is true when considered in connection with the elevation of the classified lands, the proportion of expense incurred for particular tracts and the proximity of the drain in question.

Relation of Designs to Assessments.—It sometimes occurs that drains are established and constructed which, because of an error in the field work, in design, in judgment, or from expediency, do not furnish the full required outlet to certain tracts of land. In case of drainage district organizations the owners are entitled to the belief that full benefits will be received, and grave injustice is done, first, if they are not properly advised of the facts before the establishment, construction and assessment of the district, and second, if they are assessed for benefits which are not enjoyed. A benefit commission cannot be definitely informed as to what action future commissioners may take, but a reasonable assumption would be that in case of reconstruction the necessary costs would be proportioned most heavily to the lands then receiving the greatest benefits, which would be those tracts at that time requiring the reconstruction. Thus in the determination of the assessment upon such areas, estimates of the proportionate cost to them of a system necessary to furnish them outlets should be made, and the probable additional expense to them of securing outlets in the future deducted from this estimated cost would in a measure indicate the fair assessments applicable to them. This point would not be of importance were all drains constructed in accordance with the natural requirements in all cases. But as many of the early districts in all communities do not furnish outlets to some of the affected lands, and as assessments in many cases have been rendered for full proportionate benefits, the consideration of this question has been forced upon those later in charge with painful persistency, emphasizing the importance of proper design or of assessment credit in case of improper design. To compute the amount of credit that should be given in any given case with any degree of accuracy, the commission or engineer member at least must be qualified to design drains and to estimate the probable results to be expected from the drains.

Comparison of Watershed Divisions.—After the cost of a drain is apportioned to all of the affected lands, and during the processes of apportionment, certain comparisons are of value as indications of benefits received by the different portions of the watershed. As before mentioned, the proportion fairly borne by sub-watershed areas may be estimated with fair accuracy. It often occurs that at some point in the course of a drain the fall is so great that all lands tributary to the main above this point could be successfully drained without the installation of such an expensive drain below as may be necessary for the drainage of the lower lands. Apparently the share of these lands so situated should be less than would be proper were their elevation such that a more expensive drain were necessary. In this way watersheds may be separated into units and comparisons made which will relatively indicate the fairness of assessments. Such comparisons are also applicable in cases where the outlet portions of drains are extended through lands in which watercourses exist of sufficient depth and capacity to constitute legal outlets for drainage districts. The vital question is whether the lands adjacent to the drain above the possible legal outlet are liable for any of the incurred cost of extending the drain. It would seem just that in case no benefits were deducible for any of the foregoing reasons, the owners of the lands should, before the establishment of the district, be allowed the privilege of deciding as to whether they are willing to bear the total cost of such an extension through their lands. If they should not be willing to do so, the extension should not be constructed by the district unless necessary to its welfare, in which case the lands above should rightfully bear some portion of the cost.

Soil Fertility.—In the case of the average watershed in such agricultural states as Illinois and Iowa, the soil is so generally fertile that differences in assessments need not be made to allow for variations in soil fertility and productiveness. The fact that a tract is sandy, rocky or peaty, and thus rendered of comparatively less value for cropping purposes, does not affect the cost of draining the watershed as a whole, but it does minimize the resulting benefits because of increased returns from the land. Land which is sandy or otherwise affected in a manner which will constitute a permanent obstacle to the productivity of the land should influence assessments to a greater extent than lands which are peaty or affected with alkali, and which are capable of being subdued. Soils which are overlaid with peat beds to depths of 6 to 24 inches require only time to subdue them, and an engineer should be qualified to estimate about the processes that will be necessary to accomplish maximum productivity in order to judge of benefits and act as advisor to land owners. These soils are unnecessarily neglected in many communities because of the hesitancy of owners to undertake their subdual, and as a consequence these lands often lie idle in a watersoaked condition for many years after outlet drains are constructed, thus leading to the popular belief that such lands are not materially benefited by outlet drains. If the peaty soil is underlaid with sand and gravel, its productive possibility is not so great because of the difficulty of retaining moisture for growing crops, but if underlaid with the finer-grained subsoils, its reclamation is only a question of time and proper methods. Complete drainage is first necessary, which may be followed by a thorough plowing and preparation of the seed bed and seeding to blue-grass and clover or similar grasses for pasturing purposes, or to timothy and alsike clover for the growth of hay crops. Pasturing serves to tramp down and reduce the peat the more rapidly. Very productive hay crops may be produced on such soils, and corn crops have been successfully grown in cases where the peat layer has been thin enough to allow the penetration of the moisture-bearing subsoil by the rootlets. The length of time required to prepare these soils for general cropping purposes will depend upon the thickness of the peat and the time necessary to reduce it sufficiently to allow of the bringing of the sub-soil to the surface by deep plowing, and will probably vary from one to six years for peat beds of 6 to 24 inches in thickness. The thicker peat beds which are valueless for agricultural purposes are undoubtedly little benefited by drainage unless some practicable use for them may be demonstrated. The possibilities of soils and the crops that may be produced upon them vary for different localities, and special studies of the influencing conditions should be made in each case before benefit assessments are spread.

System for Reduction of Benefits.—It thus appears that the division of costs cannot be reduced to an absolute system, as the conditions vary so radically and the considerations affecting benefits are so interdependent that each benefit factor cannot be segregated and definite proportionate values assigned to it. But some method is necessary for the approximate derivation of assessments before comparisons and adjustments are possible. A system is here suggested by the use of which percentage values may be assigned to each of the class of benefits discussed and comparative assessments computed for each tract according to the benefit per acre. The necessary form for the ready use of this method is shown in Fig. 33, and a portion of an imaginary district assessment computed as an illustration.

In the order listed, the owner's name and the description of the tract is entered. Instead of listing the classifications of swamp, wet, low and dry and the corresponding number of acres in each of the two succeeding columns, "Kind of Land" and "Acres," a large amount of computation may be eliminated and practically the same results arrived at by reducing the classifications to an equivalent swamp acreage value and entering this reduced acreage for the tract in the column "Acres" following the classification of swamp. If the separate classification plan were followed throughout the swamp lands of the lowest elevation or those requiring the greatest expenditure to effect an outlet would be given 100 per cent in the list "Class of Land," and proportionately less percentages assigned the higher the comparative elevations of the swamp lands, amounting to the percentages applicable to dry lands in case of elevations allowing of natural drainage outlets. Those wet lands lying in the main valley would be given a uniform percentage of 50 to 60 per cent, upon the theory that wet lands receive this proportion of benefits as compared to swamp lands and that the wet lands require uniformly similar proportionate sizes and depths of drains. In cases of wet lands so situated as to require excessive depths for any reason, the percentage would be increased. Those wet lands upon the slopes and in the draws would receive a less percentage as their elevation increased. Because of the natural advantages as regards sizes, and depths and because of the less necessity for any drainage, low lands would be given 30 to 10 per cent, and dry lands uniformly 10 per cent. By the use of the simplified plan suggested the reductions to equivalent swamp acreage method would be effected in accordance with the following illustration:

5 A. swamp X 100% = 5.00 swamp acres.
10 A. wet X 60% = 6.00 " "
15 A. low X 30% = 4.50 " "
10 A. dry X 10% = 1.00 " "
Total = 16.50 " "

METHOD OF COMPUTING BENEFIT ASSESSMENTS.

Extract from Benefit Assessment Apportioned on Lands in Drainage District No. 1 on Account of Expense of Construction of Ditch.

Name of Owner	Land Descriptions	Kind of Land	Acres	Class of Land	PROXIMITY		Product	Sum	Assess-ment	Remarks
					to Drain	to Outlet				
....	N.W. ¼, N.W. ¼, 6-90-27	S	6	100	100	100	6.00	....	....	Common
....	....	W	12	60	100	100	7.20	....	....	Multiple =
....	....	L	13	30	100	100	3.90	....	....	$25.00
....	....	D	7	10	100	100	.70	....	....	....
								17.80	445.00	
....	S.W. ¼, N.W. ¼, 6-90-27	S	15	60	80	70	5.04	....	....	....
....	....	W	6	60	80	70	2.01	....	....	....
....	....	L	11	30	80	70	1.85	....	....	....
....	....	D	8	10	80	70	.45	....	....	....
								9.35	233.75	
....	N.E. ¼, N.W. ¼, 6-90-27	S	2	80	60	100	.96	....	....	....
....	....	W	13	60	60	100	4.68	....	....	....
....	....	L	15	30	60	100	2.70	....	....	....
....	....	D	10	10	60	100	.60	....	....	....
								8.94	223.50	
....	S.E. ¼, N.W. ¼, 6-90-27	S	1	30	70	50	.11	....	....	....
....	....	W	2	30	70	50	.21	....	....	....
....	....	L	25	20	70	50	1.75	....	....	....
....	....	D	11	10	70	50	.38	....	....	....
								2.45	61.25	
....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....

FIG. 33—Method of Computing Benefit Assessments

This reduced acreage is then entered as swamp acres and as the per cents representing the class of the land have already been considered in reducing the acreages, no entry is made under the heading "Class of Land" in using this method. The per cents assigned to the different classes of land for reduction purposes necessarily vary as they would were the processes effected without reducing the acreages in this manner. For instance, the elevation of the tract might be such that the 5 acres of swamp should be assigned a rating of 20 per cent in the third column, the wet 20 per cent, the low 10 per cent and the dry 10 per cent, in which case the reduced acreage value would equal 5.5 acres. Figure 33 illustrates the application of the plan without reducing the acreages and the same district is computed in accordance with the simplified system in Fig. 34 to show its simplicity and the fact that the same results are arrived at in both cases. The use of the reduction method results in less computation, with consequent less liability of errors, and presents the comparative conditions of the lands in a simpler manner, which admits of more intelligible comparisons. It is a difficult matter to make comparisons between different tracts by considering the four classifications and their varying percentages separately, but when the reductions are thus made to equivalent swamp acres all tracts are placed upon a common basis as concerns the quality and elevation of the land. Comparisons may be made upon this basis which are intelligible to land owners, attorneys, judges and others, and which prove of great assistance in first arriving at equitable assessments and later in defending these assessments in court if necessary. A blueprint of the district, with the total assessment, number of reduced swamp acres, and rate of assessment per swamp acre, noted in order with a yellow pencil upon each tract, graphically presents data to a judge or jury which effectively discloses the fallacy of general statements and arguments litigants may make. It is of course necessary to consider these swamp acres and rates per swamp acre in connection with the location of the tracts and other factors, but the effect of this plan is to greatly minimize and simplify the items which must be considered.

Under the heading "Proximity to Drain" the percentages for all classes are listed at 100 per cent for those tracts through which the drain extends, and proportionately less percentages the farther distant a tract is situated from the

SIMPLIFIED METHOD OF COMPUTING ASSESSMENTS.

Extract from Benefit Assessment Apportioned on Lands in Drainage District No. 1 on Account of Expense of Construction of Ditch.

Name of Owner	Land Descriptions	Kind of Land	Acres	Class of Land	Proximity		Product	Sum	Assessment	Remarks
					to Drain	to Outlet				
....	N.W. ¼, N.W. ¼, 6-90-27	S	17.8	....	100	100	....	17.80	445.00	....
....	S.W. ¼, N.W. ¼, 6-90-27	S	16.7	....	80	70	....	9.35	233.75	....
....	N.E. ¼, N.W. ¼, 6-90-27	S	14.9	....	60	100	....	8.94	223.50	....
....	S.E. ¼, N.W. ¼, 6-90-27	S	7.0	....	70	50	....	2.45	61.25	....
....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....

FIG. 34—Simplified Method of Computing Assessments

drain, as lands 40 rods distant at 70 per cent, 120 rods distant 50 per cent. In small flat districts it is unnecessary to make use of the column "Proximity to Outlet," but it is useful in the assessment of the more extensive districts. In such cases allowances may be made for the bodies of lands in sub-watersheds or in the main watercourse draw, which should bear less than the average proportion because of comparative independence of certain sections. For instance, lands situated along the main watercourse of similar proportionate elevations should be rated at 100 per cent, those lands in sub-watersheds which might use only a small portion of the main and not be subject to overflow at 10 per cent and upward, and those lands adjacent to the main, which possess elevation advantages as mentioned under the topic "Comparison of Watershed Divisions," at 40 per cent upward, depending upon the natural advantages enjoyed. After these percentages are thus assigned to all of the tracts, these and the number of acres are multiplied together and the product listed in the column "Product" for each classification. Because of the large number of units in such products it is convenient to simplify it by setting off about four decimal points for all products, which does not affect the final result. Then in order the products are totaled for each tract and listed under the heading "Sum," and the total sum of these results thus obtained for all of the farm lands in the district divided into the amount of funds to be raised gives as a quotient a common multiple, which in turn multiplied by the sum of the points for each tract results in the assessment for that tract. In computing the total assessments to be paid by the farm lands, all assessments levied against highways, railroads and town lots must first be deducted from the total cost and the balance apportioned to the farm lands. It is best, in estimating the total amount of funds to be raised, to allow a liberal percentage in addition to the contract price to provide for all necessary incidental expense, as future reassessments to provide for deficiencies are always productive of dissatisfaction.

A commission experienced in the levying of assessments can accomplish surprisingly accurate results by the use of this system, and an incompetent commission very unjust results by the use of the same method. In all cases the resulting assessments should be copied upon a plat and comparisons made in the light of influencing suggestions that can be made by the members of the commission. After such a review a commission will often find it advisable to alter the results in individual cases, which a commission should not hesitate to do if evidently just, as the percentages cannot be so fairly proportioned in all cases as to render the results absolutely fair. If the office work is transacted at a considerable lapse of time after the completion of the field work or classifying, or if the district is large, final comparisons are best made after generally reviewing the lands of the district. The assessment figures may be readily transferred to white prints for field and office comparisons by the use of a common pencil, but if blueprints are used, black marks are not legible upon them. A yellow crayon or pencil will make reasonably visible and legible marks upon blueprints. Also after the comparisons and alterations have been completed the assessment sheets are usually unfit for filing with the authorities. Because of this objection and because it is advisable not to make public all the processes used in arriving at the results, the assessments and descriptions may be relisted in any convenient form or in the particular form prescribed by state law; but in all cases assessment reports should list the ownership and description of the tracts affected and the total number of acres assessed for benefits for each tract. The classifications may

METHOD OF REPORTING BENEFIT ASSESSMENTS.

Benefit Assessment for .... County, Drain Number ......

Name of Owner	Description of Land	Acres	Classification	Points of Benefit	Assessment
......	S.W. 4, S.E. 4, 30-91-29	4	8	32	$ 9.90
......	S.W. 4, S.E. 4, "	17	16.8	285.6	88.55
......	S.E. 4, S.W. 4, "	12	19	228	70.70
......	N.E. 4, N.E. 4, 31-91-29	29	51.5	1441.3	446.80
......	S.E. 4, N.E. 4, "	39	79	3081	955.10
......	N.E. 4, S.E. 4, "	11	100	1100	341.00
......	N.W. 4, N.E. 4, "	39	43.9	1712.1	530.75
......	S.W. 4, N.E. 4, "	34	68.1	2315.4	717.80
......	N.E. 4, N.W. 4, "	30	18.3	549	170.20
......	S.E. 4, N.W. 4, "	24	73.4	1761.6	546.10
......	N.E. 4, S.W. 4, 32-91-29	3	53	159	49,30
......	N.W. 4, S.W. 4, "	6	39	234	72.55
......	S.E. 4, N.W. 4, "	1	60	60	18.60
......	S.W. 4, N.W. 4, "	35	45.3	1585.5	491.50
......	Highways in .... Twp.			726	225.05
			Total =	15270.5	$4733.90

FIG. 35—A Method of Reporting Benefit Assessments

be filed separately upon the section sheets. Also assessment reports should include a summary of the assessments as proportioned upon each tract for benefits derived from the different main or branch drains in addition to the general report of the total assessments. Figure 35 illustrates the method of reporting assessments as required by a number of state laws, and Fig. 36 illustrates a method of reporting the summary of assessments for the different drains. Such a summary is useful in determining the justice of assessments by the public and courts, and serves as a guide in the relevying of assessments for future repairs and improvements.

METHOD OF REPORTING A SUMMARY OF ASSESSMENTS.

Amounts Assessed to Main and Branches Separately, ... County,

Drain No. ....

Description	Main		Branch No. 1		Branch No. 2	
	Acs.	Assessment	Acs.	Assessment	Acs.	Assessment
S. E. 4, S. E. 4, 30...	4	$ 3.95		$	4	$ 5.95
S. W. 4, S. E. 4, " ...	17	29.75			17	58.80
S. E. 4, S. W. 4, " ...	12	18.30			12	52.40
N. E. 4, N. E. 4, 31...	29	217.85			24	228.95
S. E. 4, N. E. 4, " ...	39	641.90	24	313.20		
N. E. 4, S. E. 4, " ...	11	193.15	11	147.85		
N. W. 4, N. E. 4, " ...	39	242.45			29	288.30
S. W. 4, N. E. 4, " ...	34	717.80				
N. E. 4, N. W. 4, " ...	30	108.40			13	61.80
S. E. 4, N. W. 4, " ...	24	546.10				
N. E. 4, S. W. 4, 32...	3	49.30				
N. W. 4, S. W. 4, " ...	6	72.55				
S. E. 4, N. W. 4, " ...	1	18.60				
S. W. 4, N. W. 4, " ...	35	424.45	5	67.05		
Highways in ..... Twp.		100.05		75.00		50.00
		$3384.60		$ 603.10		$746.20

FIG. 36—A Method of Reporting a Summary of Benefit Assessments

Assessment of Town Lots.—Town lots are included in the watersheds of some districts, and it is oftentimes proper that because of the greater benefits to this class of property proportionately greater assessments should be levied. In case the drain extends through the town limits and additional capacity is designed to care for flood waters more rapidly, the excess cost incurred should rightfully be assessed to the town property affected. In all cases where drainage is necessary, the resulting benefits are greater because of the benefits resulting from the drainage of streets and cellars. But if the town property is of sufficient elevation to possess a natural outlet, consideration should be given to this item as well as for farm lands. Town lots and streets are most conveniently assessed by determining the total amount to be borne by them and pro-rating this amount among them according to areas, elevations and location.

Assessment of Highways and Railroads.—Highways and railroads are usually assessed on the lump sum basis, no rules being as yet set by state drainage laws for the determination of this sum. Comparisons may be made in both cases by computing the acreages affected and about the average assessment per acre for similar lands. But because of the different purposes for which the land is used, the actual benefit or saving in construction and up-keep may justify a much greater than the proportionate assessment. In estimating the total economy that may be effected because of the construction of the drain in such cases, it must be remembered that no greater percentage of total benefit is justifiable as an assessment than the assessment upon farm lands bears to the increased value of the farm lands arising from the installation of the drain. Although highways may serve large communities outside of the district and railroads may receive greatly increased tonnage for transportation, such advantages can hardly be chargeable as benefits because of their indirect and speculative character.

Proper benefit items for consideration in the case of highways are the removal of water or the making possible of such removal from the road right of way, resulting in fewer and smaller bridges, less necessity for and cheaper maintenance of grades and the rendering of the roads more constantly passable. Railroads may be benefited because fewer and shorter bridges and trestles and less maintenance expense for them may be required, grades may be rendered more stable by the removal of water and the consequent freedom from the action of burrowing animals and from the heaving and settling of the embankment because of freezing and thawing, the expense of the up-keep of fences, poles and ties may be considerably reduced, and generally the roadbed and all affected property may be benefited by reason of less maintenance and reconstruction expense. Highways and railroads are often so situated that the construction of the drain will not in any way affect their condition and maintenance, in which cases only a nominal assessment is permissible.

As the determination of such assessments must largely be a matter of opinion and estimates, often by persons unacquainted with railroad and highway costs, it is especially important that the commissioners carefully view such properties, noting all points affecting benefits and acquiring all information available in order to insure fairly equitable assessments. In accomplishing this purpose estimates of all the economies effected per annum capitalized at the prevailing rate of interest indicates the amount of investment that would be necessary to accomplish this saving of expenditures.

Lack of Uniformity of Assessments.—The question of division of costs of drainage systems is interpreted in detail as variously as there are communities and individuals connected with such duties. The differences in opinion have extended not only to details, but have in many cases been as divergent in regard to the basic principles. This is largely the result of the newness and complexity of benefit questions, the absence of literature on the subject, the lack of instruction in colleges and of co-operation among engineers—conditions which the future promises to correct.

CHAPTER IX

THE QUALITY AND INSPECTION OF DRAIN TILE

The specifications governing the quality of drain tile have generally only related to the shape of the tile, the degree of hardness and the condition as to cracks and flaws. As a rule little consideration has been given to the actual strengths that should be provided to withstand the earth pressures coming upon them, except in isolated cases and those cases where failures have occurred. This laxity has been largely the result of an absence of data relative to earth pressures and tile strengths. Future specifications will undoubtedly be more and more based upon an analysis of soil pressures, and tile designed accordingly.

Cross-Sections of Tile.—Since clay tile cannot be successfully manufactured to a true circular cross-section because of the warping which inevitably occurs during the process of burning and drying, it is not best to include a specification requiring that tile be truly circular, especially since the warping action is the more pronounced in the more desirable hard-burned tile. It is also seriously detrimental to the capacity of the drain to allow the use of the more irregular, egg-shaped tile. A maximum variation of 3 per cent in the diameter of tile should as a rule not be exceeded.

Imperfections in Tile.—A customary specification is one requiring that all tile delivered on the line of ditch be free from cracks, and this general provision is often the cause of serious disagreements. Tile companies and contractors are naturally desirous of reducing their percentage of loss as much as possible by placing as many of the delivered tile as the engineer will allow. Without question, tile for any drainage use which are cracked in manufacture or transportation throughout their entire length should be rejected. It is more difficult to classify the extent to which minor cracks should be allowed, although the limitations should be so stated and enforced as to prevent the use of tile the strength of which is seriously impaired. In the more stable trenches a crack may safely be permitted in one end of the tile which does not exceed in length 20 per cent of the length of the tile, or if one crack extends inward from each end of the tile the sums of their lengths should not exceed 30 per cent of the length of the tile, it being assumed in both cases that the tile are designed with ample strength factors of safety. In case the tile are to be installed in cavy soil, more nearly perfect tile should be required. Small fire checks in the body of the tile do not seriously impair their strengths, while larger ones or a number of checks occurring in the same tile will result in greatly reduced strength. The testing of a few cracked and checked tile in a testing machine will demonstrate the extent to which they may be safely allowed in any given case.

Aside from the breaking and cracking of the tile which occurs in railroad transportation, which breakage is a matter for adjustment between the railway company and tile company or contractor, a large percentage of the tile is often cracked and broken by the tile haulers. Much of this latter loss results from the carelessness of the haulers in unloading them from the cars, reloading them upon the racks and unloading the tile along the line of ditch. Much of this loss may be eliminated by the employment of careful, experienced haulers and the educating of haulers to the facts that drain tile will not withstand sudden jars and rough usage, that they should be rolled instead of dropped and that they should be bound in place upon the tile rack to prevent jarring. The engineer should interest the contractor in these precautionary measures, incidentally to protect the interests of the contractor, but principally to prevent the formation of hair cracks, checks and the general disturbance of the strengths of all the tile subjected to rough handling.

Lengths of Tile.—Specifications as to lengths of tile are usually unnecessary, as tile are uniformly manufactured in standard lengths of 2, 2½ and 3 ft. in the larger sizes, practically all hard-burned and vitrified tile being also 2 ft. in length in the smaller sizes. Practically all factories manufacturing the softer grades of small tile conform to the standard length of 12 in. Hence if the better grade of tile is desired, it is not best to limit the lengths of any sizes to 12 in., especially as the 2-ft. lengths furnish a sufficient number of joints for the entrance of ground waters. The accuracy of the last statement is clearly evident to engineers acquainted with the difficulties of sealing sewers against the entrance of ground waters.

Hardness of Tile.—The degree of hardness to which all clay tile are to be burned may be fixed by some characteristic for the sizes required, as under loose specifications tile companies manufacturing softer grades of tile will insist that their tile conform to the specifications, and owing to the attractiveness of cheaper cost the contractors will be particularly anxious to buy of these companies. Four general divisions as to the hardness and finish of tile are common: soft, hard-burned, vitrified and salt-glazed.

The use of soft tile, although seriously advocated in the past by land owners, will not be here considered, as both theory and practice have proven the harder-burned tile to be stronger and more durable. Hard-burned tile differ from the soft tile of the same grade of material very little in color, excepting that they are of a perceptibly darker shade. According to their distinctive appellation they are subjected to greater heat in the kiln, sufficient, if properly applied, to burn them uniformly hard throughout the walls of the tile. Tile thus burned should emit a clear ring or bell sound when tapped with a hammer. Vitrified tile generally resemble the hard-burned, excepting that the outside surfaces are more polished and smoother in appearance because of the application of sufficient excess heat to fuse or vitrify the outer surfaces, the color and appearance of the interiors of the walls being similar to that of hard-burned tile. Glazed tile are not necessarily subjected to a more intense heat than the vitrified, but their surfaces are fluxed and glazed by the application of salt in the kilns when the temperature is at the proper degree, resulting in tile with very hard, glassy wall exteriors and vitrified wall interiors. The glazing of tile is sometimes objected to because of the hiding of defects by the glazing. As a rule, however, the degree of heat necessary to successfully glaze tile is usually sufficient to insure their proper burning; cracks and checks are generally discernible in glazed tile; enough tile are broken to show the general condition of the wall interiors; hammer and machine tests will disclose serious defects; and the glazing is an advantage in that it aids in waterproofing the tile against the penetration of moisture.

As the cost of manufacture increases for each grade in the order noted above, it is only just that competing contractors be informed in comprehensible terms as to which grade or grades they must furnish. All references to such arbitrary classifications of hardness and finish may be eliminated, being substituted by absorption tests, but owing to the fact that standards of manufacture are closely adhered to by clay tile manufacturers with respect to these four divisions, for the sake of clearness the degree of hardness may be best specified by reference to classes. Maximum absorption test should also be fixed for each class specified, which maximum per cents of absorption should be approximately: soft tile, 10 per cent; hard-burned tile, 8 per cent; vitrified tile, 6 per cent; and glazed tile, 5 per cent.

Concrete tile are not so readily analyzed as to density or hardness classes, as the method of accomplishing density—the manufacture and setting of concrete—should not be varied. The too general argument in favor of concrete tile, that they are more porous and will thus admit ground waters more readily, cannot be too severely condemned. While the disintegrating action of percolating water through the walls of the tile may not cause the dissolution of the cement, as the opponents of concrete tile have endeavored to prove, the fact remains that percolating water does tend to disintegrate soft tile of any material, and every precaution should be taken to secure dense, waterproof tile walls. As the hardness of concrete depends upon the quality and cleanliness of the gravel or other aggregate, the grade of the cement, the cleanliness of the water, the thoroughness of the mixing of the ingredients, the method of tamping or consolidating the concrete in the forms and the effective curing of the completed tile, it is essential that the rigid specifications in regard to all these factors be provided that the tile be manufactured by competent, experienced concrete workers, and that their manufacture be constantly inspected by a competent inspector. The slogan that "anybody can make concrete" has no place in the manufacture of concrete tile.

Earth Pressures in Tile Trenches.—Although there have been theories advanced as to the earth pressure actually transferred to the tile in trenches, there have been until recently few experiments in this direction conducted under actual trench conditions. A series of experiments conducted in trenches by the Experiment Station of the Iowa State College, under the supervision of Dean A. Marston, have not only demonstrated that drain tile in many cases have not been manufactured with a sufficient factor of safety, but have also furnished data and proofs upon which to intelligently base field investigations and specifications. In these tests the pressures upon the tile were measured by a pressure gauge and the results compared with a tentative formula devised by Prof. Marston to be used in connection with the Ames and other testing machines. These tests indicated that the results of tests made with a machine compare very closely with the earth pressures that tile will withstand in trenches, and that the earth pressures as computed by the Marston Formula compare closely with the actual earth pressures on tile in trenches. Based upon these tests, four truisms are deduced in Bulletin No. 31 issued by the Iowa State College, which are:

(1) The weight of fill is carried partly by the pipe and partly by the friction against the sides of the trench.

(2) Within the limits of width of ordinary tile ditches, the wider the ditch, the greater the pressure, but with the same width of trench the diameter of the pipe does not affect the load, which is as great for a small pipe as for a large pipe in the same width ditch.

(3) The proportion of the weight of filling carried by the pipe decreases as the depth of fill gets greater, and after the depth of fill becomes equal to 10 times the width of the trench there is practically no increase in the load on the pipe.

(4) The load on the pipe will depend upon the weight of the ditch filling per cubic foot and its degree of saturation.

The Marston formula for earth pressures on pipes is:

$$W = C\ w\ B^2$$

in which

W = Total pressure on pipe in lbs. per linear foot.
C = A constant, the value of which depends upon the ratio H/B and the character of the trench filling. (Its values are given in Table 15.)
w = The unit weight of filling materials in lbs. per cu. ft. (Some values are given in Tables 16 and 17.)
B = The width in feet of the trench at a point level with the top of the pipe.

By the use of Tables XV, XVI and XVII, the pressure of earth in any given case is readily computed or the weights resting on pipes may be read directly from Table XVIII with-

TABLE XV—APPROXIMATE VALUES OF C FOR USE WITH MARSTON FORMULA.

H = Height of Fill in Feet Over Pipe.
B = Width of Trench at Top of Pipe.
C = Average Vertical Pressure per Sq. Ft. at Top of Pipe in a Trench 1 Ft. Wide, Due to Ditch Filling Weighing 1 Lb. per Cu. Ft.

Ratio H, B	For Damp Top Soil and Dry and Wet Sand	For Saturated Top Soil	For Damp Yellow Clay	For Saturated Yellow Clay
0.5	0.46	0.47	0.47	0.48
1.0	0.85	0.86	0.88	0.90
2.0	1.47	1.51	1.56	1.62
3.0	1.90	1.99	2.08	2.19
4.0	2.22	2.35	2.47	2.65
5.0	2.45	2.61	2.78	3.02
6.0	2.61	2.81	3.01	3.32
7.0	2.73	2.95	3.19	3.55
8.0	2.83	3.06	3.33	3.74
9.0	2.88	3.14	3.44	3.89
10.0	2.92	3.20	3.52	4.01
11 0	2.95	3.25	3.58	4.11
12.0	2.97	3.28	3.63	4.19
13.0	2.99	3.31	3.67	4.25
14.0	3.00	3.33	3.70	4.30
15.0	3.01	3.34	3.72	4.34
Infinity	3.03	3.38	3.79	4.50

TABLE XVI—MEASUREMENTS OF WEIGHTS OF TRENCH FILLING PER CUBIC FOOT (NOT COMPRESSED).

No. of Tests	Kind of Soil	Condition of Soil	Weight in Lbs.
3	Black top soil	Loose, wet, 20% water	60
3	Black top soil	Loose, damp, from 2′ depth	75
3	Black top soil	Saturated	100
3	Black top soil, mixture of black	Saturated, 25% water	108
4	Top soil and yellow clay	Loose, wet, 19.4% water	80
3	Yellow clay, slightly sandy	Loose, damp, from 4′ depth	75
3	Yellow clay, very sandy	Loose, damp, from 6′ depth	88
3	Yellow clay	Saturated, 17% water	127
2	Yellow clay	Saturated, 26% water	145
4	Blue clay from 15′ depth	Loose, dry, hard, had to be picked	83
1	Sand	Dry	99
1	Sand	Damp, 5% water	92
1	Sand	Wet, 15% water	121

TABLE XVII—MEASUREMENTS OF THE WEIGHTS PER CUBIC FOOT OF SOLID, UNDISTURBED SOIL IN PLACE.

Kind of Soil	Damp—Lbs.	Saturated—Lbs.
Black top soil......................	96.8	108.4
Black top soil......................	96.7	107.6
Black top soil......................	90.5	99.2
Black top soil......................	93.8	106.0
Averages =	94.0	105.0
Yellow clay, 2½′ depth..............	116.5	119.9
Whitish clay, 3½′ depth.............	124.9	126.5
Average for clay sub-soil =	121.0	123.0
Sandy clay, 2½′ depth..............	113.9	122.2
Sandy clay, 3′ depth................	98.9	107.8
Sandy clay averages =	106.0	115.0
Clayey sand, 4′ depth................	121.3	133.8
Clayey sand, 4′ depth................	121.2	132.0
Coarse pebbles and clayey sand.......	127.2	131.2
Clayey sand and gravel..............	123.0	132.0
Blue clay, 4½′ depth................	114.0	118.0
Sandy yellow clay, 1.7′ depth.........	104.4	.....
Yellow clay, 3.3′ depth...............	120.0	.....
Mixture of yellow and blue clay, 16′ depth	136.0	.....
Blue clay, 18′ depth................	137.0	.....
Blue clay, 20′ depth.................	137.0	.....
Yellow clay a few rods from experimental ditch, 9′ depth..............	133.0	.....
Yellow clay a few rods from experimental ditch, 4′ depth.............	129.0	.....

TABLE XVIII—APPROXIMATE ORDINARY MAXIMUM LOADS ON DRAIN TILE AND SEWER PIPE IN DITCHES FROM COMMON DITCH FILLING MATERIALS IN POUNDS PER LINEAL FOOT

BREADTH OF DITCH IN FEET AT TOP OF PIPE

Height of Fill in Feet above Top of Pipe	1	2	3	4	5	1	2	3	4	5
	Partly Compacted Damp Top Soil, 90 Lbs. per Cu. Ft.					Saturated Top Soil, 110 Lbs. per Cu. Ft.				
2	130	310	490	670	830	170	380	600	820	1020
4	200	530	880	1230	1580	260	670	1090	1510	1950
6	230	690	1190	1700	2230	310	870	1500	2140	2780
8	250	800	1430	2120	2790	340	1030	1830	2660	3510
10	260	880	1640	2450	3290	350	1150	2100	3120	4150
	Dry Sand, 100 Lbs. per Cu. Ft.					Saturated Sand, 120 Lbs. per Cu. Ft.				
2	150	340	550	740	930	180	410	650	890	1110
4	220	590	970	1360	1750	270	710	1170	1640	2100
6	260	760	1320	1890	2480	310	910	1590	2270	2970
8	280	890	1590	2350	3100	340	1070	1910	2820	3720
10	290	980	1820	2720	3650	350	1180	2180	3260	4380
12	300	1040	2000	3050	4150	360	1250	2400	3650	4980
14	300	1090	2140	3320	4580	360	1310	2570	3990	5490
16	300	1130	2260	3550	4950	360	1350	2710	4260	5940
18	300	1150	2350	3740	5280	360	1380	2820	4490	6330
20	300	1170	2420	3920	5550	360	1400	2910	4700	6660
22	300	1180	2480	4060	5800	360	1420	2980	4880	6960
24	300	1190	2540	4180	6030	360	1430	3050	5010	7230
26	300	1200	2570	4290	6210	360	1440	3090	5150	7460
28	300	1200	2600	4370	6390	360	1440	3120	5240	7670
30	300	1200	2630	4450	6530	360	1440	3150	5340	7830
Infinity	300	1210	2730	4850	7580	360	1450	3270	5820	9090
	Partly Compacted Damp Yellow Clay, 100 Lbs. per Cu. Ft.					Saturated Yellow Clay, 130 Lbs. per Cu. Ft.				
2	160	350	550	750	930	210	470	730	1000	1240
4	250	620	1010	1400	1800	340	840	1337	1870	2370
6	300	830	1400	1990	2580	430	1140	1900	2630	3410
8	330	990	1720	2500	3250	490	1380	2360	3360	4400
10	350	1110	2000	2920	3880	520	1570	2760	3980	5270
12	360	1200	2220	3320	4450	540	1730	3100	4560	6050
14	370	1280	2410	3650	4950	560	1850	3410	5050	6760
16	370	1330	2570	3950	5400	570	1940	3660	5510	7440
18	380	1380	2710	4210	5810	570	2020	3880	5930	8060
20	380	1410	2830	4450	6180	580	2090	4070	6280	8610
22	380	1430	2920	4640	6500	580	2140	4240	6610	9130
24	380	1450	3000	4820	6800	580	2180	4380	6910	9590
26	380	1470	3060	4980	7080	580	2210	4500	7160	10010
28	380	1480	3120	5100	7310	580	2240	4610	7380	10430
30	380	1490	3170	5230	7530	580	2260	4700	7590	10780
Infinity	380	1520	3410	6060	9480	580	2340	5270	9360	14620

TABLE XIX—AVERAGES OF STRENGTHS OF CLAY DRAIN TILE

Diam.	Wall Thickness	Length	Total Weight	Breaking Load Pounds per Lin. Ft. Max.	Min.	Av.	Modulus of Rupture Pounds per Sq. In. Max.	Min.	Av.	Absorption, Per Cent Max.	Min.	Av.	No. of Pipe Tested
5″	.63″	12″	9	1700	1400	1530	1110	920	960	18.5	15.0	16.3	4
5″	.63″	13″	...	680	640	650	430	400	410	....	....	....	3
6″	.65″	12″	13	2250	1290	1700	1710	1020	1380	8.2	2.6	4.8	13
6″	.65″	12″	13	2500	1860	2160	2430	1420	1820	7.3	2.9	5.4	12
6″	.65″	12″	13	1860	625	1270	1570	490	1070	7.7	4.0	6.1	*5
6″	.62″	13″	...	1110	570	760	840	400	550	...	....	....	3
7″	.63″	13″	...	1230	810	960	1030	630	800	....	....	....	3
8″	.65″	12″	16	2220	1410	...	1900	1080	....	19.0	3.6	....	2
8″	.73″	29″	...	1980	1140	1600	1350	840	1130	....	....	....	6
8″	.70″	13″	...	1060	760	890	780	570	670	....	....	....	3
12″	1.00″	25″	83	1770	840	1430	1050	450	770	7.6	3.1	5.0	37
12″	.90″	12″	36	4160	2000	2810	3030	1320	1930	7.6	3.9	5.7	5
12″	.90″	12″	36	3150	2080	2730	2100	1380	1790	8.1	6.5	7.1	†5
16″	1.10″	25″	115	2010	1500	1710	1220	680	970	....	....	....	5
16″	1.10″	25″	115	1560	1290	1430	940	750	850	....	....	....	3
16″	1.10″	25″	115	1870	1440	1670	1130	860	1010	....	....	....	3
16″	1.10″	25″	115	....	....	1700	....	....	1020	....	....	....	1
18″	1.30″	25″	152	2010	1550	1740	1050	650	870	8.8	4.1	5.5	5
20″	1.30″	30″	206	1630	1170	1480	1170	770	860	5.5	4.1	5.0	4
24″	1.40″	30″	315	2400	1460	2000	1540	880	1180	4.4	4.0	4.1	5
28″	2.00″	30″	460	4200	1960	3370	1300	620	1060	5.6	4.5	5.0	4
30″	2.00″	30″	470	4450	2740	3390	1430	1000	1300	4.6	2.8	3.8	5

* From same lot as above but immersed in water for 30 days and tested while saturated.

† From same lot as above but immersed in water for 3 weeks and tested while saturated.

The 18″, 20″, 24″, 28″, 30″, the second set of 8″, and the first set of 12″ are classed as vitrified, salt-glazed tile, while the others are common drain tile.

out computation, all three tables being taken, complete or reduced, from the same source as Table XV. (Iowa State College, Bulletin No. 31.)

Strength of Drain Tile.—While many of the drains, in which drain tile of standard dimensions were used, have given apparent satisfaction, especially in the shallower trenches, there have been a considerable number of failures reported in the case of the deeper trenches. Doubtless also many of the tile in existing tile trenches are in a cracked condition, but have not completely failed, and have consequently not been discovered.

Experience indicates that the earth compacts and arches in trenches to such an extent that it will carry heavy loads even though cavities have formed directly over the tile or sewer pipe to such an extent that little or no pressure is transferred directly to the pipe. However, this condition does not exist immediately following the construction of the drain while the earth filling is still in a loose condition, and tile should be designed for the pressures exerted at this time. The proper factor of safety for tile strengths is yet undetermined from experience and experiments, but since tile have withstood pressures as successfully as they have in known cases where there have been few or no factors of safety, it is probably safe to specify that tile shall withstand pressures equal to 1½ times the weight of the earth as computed by the Marston formula for stable trenches, and twice the pressure when the trench banks are unstable.

The results of recorded tests upon drain tile have indicated that the breaking strength and modulus of rupture of clay tile have been fairly uniform for a number of tests and that the strengths of the tile have increased somewhat proportionately with increases in size. Tests on concrete tile have indicated that the breaking strengths have varied more between different tests upon similar sizes and that the strengths have not increased in proportion to the increasing diameters. Tables XIX and XX are condensed from Iowa State College Bulletin No. 31, and are a record of average strengths of a large number of test samples. These facts indicate:

(1) That clay tile as manufactured are sufficiently strong for the shallower trenches.

(2) That clay tile as manufactured are not sufficiently strong for the deeper trenches.

(3) That good concrete tile of the smaller sizes are sufficiently strong for average trenches.

(4) That good cement tile of the larger sizes and of the usual dimensions are not sufficiently strong for average trenches.

(5) That larger sizes of concrete tile should be strengthened by scientific manufacture, thicker walls and reinforcement when more economical than thicker walls.

(6) That the strengths of drain tile cannot be standardized, but must be varied with the earth pressures to be borne.

The specifications of the Interstate Tile Manufacturers' Association for the manufacture of plain concrete tile are as follows:

Material. (1) Cement. The cement shall meet the requirements of the standard specifications for Portland Cement of the American Society for Testing Materials. A bag of Portland cement shall be considered as one cubic foot.

(2). Fine aggregate shall consist of sand, crushed stone, or gravel screenings, graded from fine to coarse, passing when dry a screen having ¼-in. diameter holes, shall be preferably of silicious materials, clean, coarse, free from vegetable loam or other deleterious matter, and not more than 6 per cent shall pass a sieve having 100 meshes per lineal inch.

(3). Mortars composed of one part Portland cement and three parts fine aggregate by weight, when made into briquets shall show a tensile strength equal to that of 1 to 3 mortar of the same consistency made with the same cement and standard Ottawa sand.

(4). Coarse aggregate shall consist of gravel or crushed stone, graded in size, which is retained on a screen of ¼-in. mesh, and not over 3 per cent of which material shall exceed in the largest dimension one-half the wall thickness of the tile. Material shall be clean, hard, durable and practically free from deleterious materials.

(5). Sands and gravel vary so greatly in the same pit that frequent tests should be made to ascertain the actual voids in the material. Then use 5 per cent more cement than enough to fill these voids.

(6). A simple way to ascertain these voids is to pack the fine aggregate solidly into a tight measure holding a cubic foot, stroke it level. Weigh a measure of water, turn it on the material in the measuring box until the water stands at the surface. After ascertaining the weight of the water so used, multiply that weight by 1½ and add to this 5 per cent, which will give the weight of cement required.

(7). Where coarse aggregate is used, determine the weight of water necessary to fill the voids, multiply by 1½ and add 10 per cent to obtain the weight of fine aggregate required. The cement shall overfill the voids in the fine aggregate as determined by the method in the paragraph above.

(8). If the material is not tested for voids as indicated above, a leaner mixture than one part cement to three parts aggregate shall not be used.

(9). Hand measuring is recommended as being most reliable. Where a mechanical proportioning mixer is used, extreme care should be exercised to see that it is measuring accurately and uniformly. Different aggregates feed so differently that each user of such mixer must test this for himself.

(10). Water. Water shall be clean, free from oil, acid, strong alkalies or organic matter.

Mixing. (11). The materials shall be mixed in a practically dry state until the cement is uniformly distributed, sufficient water added to obtain the desired consistency, and the mixing continued until the mass is uniform in color.

(12). Machine Mixing. When the conditions will permit, a machine mixer shall be used.

(13). Hand Mixing. When it is necessary to mix by hand, the mixing shall be on a water-tight platform and the materials shall be turned until they are homogeneous in appearance and color.

(14). Consistency. Hand or machine made tile. The consistency of the concrete shall be such as to show web-like markings on the surface of the tile when the forms are removed. The concrete must be used within 30 minutes after time of mixing.

(15). Slush Tile. The consistency of the concrete shall be such that it will be forced into every part of the mold by jarring or tamping. The concrete must be used within 40 minutes after the time it is mixed. Slush tile may be made outside of established factories. The use of pneumatic hand tools shall be considered as hand mixing.

(16). Retempering. Retempering mortar or concrete, i. e., remixing with water after it has partially set, shall not be permitted.

Forming. (17). Under no circumstances shall tile be made in a temperature lower than 40° F. Tile shall be formed so as to prevent laminations or planes of weakness.

(18). Machine Made and Hand Tamped Tile. Tile shall be made in such a manner as to insure a dense and uniformly packed product with smooth ends and surfaces.

(19). Slush Tile. Concrete for slush tile shall be forced into the metal forms by jarring or tapping in such a manner as will obtain a smooth, dense surface and shall remain undisturbed in the form for at least 12 hours.

Curing. (20). Steam Curing. Within 60 minutes after the jackets have been removed from the tile they shall be subjected to an atmosphere saturated with moisture, the tempera-

TABLE No. XX—AVERAGES OF STRENGTHS OF CONCRETE DRAIN TILE

Diam.	Proportions	Age, Months	Wall Thickness	Total Length	Total Wgt.	Breaking Load —Pounds per Lin. Ft.—			Mod. of Rupture —Pounds per Sq. In.—			Absorption, Per Cent			No. of Pipe Tested
						Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	
5″	1-4	28	0.6″	12″	..	1450	1100	1210	2080	1270	1580	....	....	....	*4
5″	1-3½	6	0.6″	12″	10	2260	1900	1920	1980	830	1380	7.3	6.8	7.1	4
6″	1-4	14	0.6″	12″	..	1140	1040	1080	1400	810	1040	....	....	....	4
6″	1-4	6	0.7″	12″	13	1770	820	1360	1210	540	910	11.6	4.1	7.5	33
8″	1-4	3	0.7″	12″	..	1230	870	1090	1010	740	850	....	....	....	6
8″	..	12	0.8″	12″	..	1980	1140	1670	1290	650	1050	....	....	....	3
8″	..	372	1.3″	30″	..	2330	1650	1880	580	370	460	....	....	....	†10
10″	1-4	24	0.9″	12″	..	1590	890	1250	1130	560	810	....	....	....	12
10″	..	372	1.3″	30″	..	950	910	930	310	300	300	....	....	....	‡2
10″	1-3	3	0.9″	12″	29	1240	1030	1110	660	820	780	7.9	7.0	7.4	3
12″	1-4	4½	1.0″	12″	..	950	560	810	640	300	490	....	....	....	4
12″	1-3½	7	1.0″	12″	..	1750	910	1290	1000	550	820	....	....	....	4
12″	..	12	1.0″	12″	..	2330	1890	2030	1030	850	910	....	....	....	3
14″	1-4	6	1.4″	12″	..	2510	1400	1850	950	430	640	....	....	....	10
14″	1-3	1	1.3″	18″	90	1300	1090	1190	590	500	510	7.0	5.5	6.6	5
14″	1-3½	1	1.2″	12″	48	940	680	850	440	320	390	13.8	11.2	12.8	3
16″	1-4	12	1.2″	12″	..	1420	1000	1250	710	500	610	....	....	....	6
16″	..	...	1.6″	24″	..	1110	1010	1060	290	260	280	....	....	....	2
16″	..	8	1.7″	24″	..	1380	1180	1280	370	320	340	....	....	....	2
18″	1-4	..	1.8″	24″	..	3850	2710	3170	1010	700	900	....	....	....	3
18″	..	1	1.8″	24″	..	....	....	1370	....	....	390	....	....	....	1
18″	1-3	14	1.8″	30″	265	1600	1590	1600	410	400	410	6.0	5.3	5.7	2
20″	1-4	10¼	1.8″	24″	..	1790	1210	1560	600	430	540	....	....	....	4
20″	1-4	..	2.0″	24″	..	3720	3340	3550	900	840	860	....	....	....	3
20″	..	7	2.0″	24″	..	2340	2280	2310	650	640	650	....	....	....	2
20″	1-3	2	1.9″	30″	300	1390	1230	1280	390	320	350	8.1	7.2	7.7	3
22″	1-4	36	2.3″	24″	..	2880	2200	2540	500	470	480	....	....	....	2
22″	1-3	14	2.1″	30″	375	....	....	1810	....	....	410	....	....	5.7	1
22″	1-3	1	2.3″	30″	380	1710	1480	1650	480	370	400	6.6	5.8	6.1	5
24″	1-3	1	2.4″	30″	462	1970	1830	1910	440	380	410	8.0	5.3	6.2	5

TABLE NO. XX—AVERAGES OF STRENGTHS OF CONCRETE DRAIN TILE—Continued

Diam.	Propor- tions	Age, Months	Wall Thick- ness	Total Length	Total Wgt.	Breaking Load —Pounds per Lin. Ft.— Max.	Min.	Av.	Mod. of Rupture —Pounds per Sq. In.— Max.	Min.	Av.	Absorption, Per Cent Max.	Min.	Av.	No. of Pipe Tested
24"	1-4	..	2.4"	24"	..	....	....	2290	....	....	480	....	....	....	1
24"	..	¾	...	24"	..	....	....	1170	....	....	....	....	....	....	1
26"	1-3	2	2.2"	24"	375	1800	1360	1580	430	360	390	8.2	7.1	7.6	2
26"	1-3	1	2.6"	30"	575	1960	1880	1900	410	320	350	7.6	5.4	6.5	5
28"	1-3	1	2.8"	30"	630	2240	2160	2200	390	360	370	6.3	5.5	5.9	5
28"	1-3	2	2.3"	30"	530	....	....	1570	....	....	500	....	....	8.4	1
30"	1-3	2	2.6"	30"	640	....	....	1460	....	....	290	....	....	5.9	1
30"	1-3	14	2.6"	30"	612	....	....	1680	....	....	360	....	....	6.0	1
32"	..	2	...	24"	..	1650	1600	1630	....	....	....	....	....	....	§2
32"	..	1⅓	...	24"	..	2250	2250	2250	....	....	....	....	....	....	¶2
32"	..	2½	...	24"	..	1850	1850	1850	....	....	....	....	....	....	2
34"	1-3	2	2.8"	30"	800	....	....	1460	....	....	290	....	....	7.7	1
34"	1-3	14	2.8"	30"	785	....	....	2070	....	....	410	....	....	5.2	1
36"	1-4	..	3.4"	24"	..	3000	2970	2900	430	350	390	....	....	....	3
36"	1-3	16	2.9"	24"	700	....	....	1980	....	....	380	....	....	....	1

* Taken from drain in ground, two years.

† From old foundation drain of old Main Building, Iowa State College; 31 years in the ground.

‡ Same as last set of 8" above, excepting that pipe were 30 years in ground and 1 year on surface.

§ Hand tamped.

¶ Machine tamped.

ture of which is not less than 70° F. and not more than 120° F. In warm weather the tile shall be subjected to steam curing for at least 48 hours and then removed from the curing chamber and piled in the yard for at least 14 days. In freezing weather the tile shall be cured for 72 hours and then removed and piled in the yard for at least 14 days.

(21). Natural Curing. In warm weather factory-made tile shall be stored in a room where they will be protected from drafts and against drying out. After hardening sufficiently the tile shall be sprinkled at least three times a day for a period of six days, after which they shall be piled in the yard for at least 24 days. In freezing weather the tile shall be stored in a room where they will be protected against drying out and where the temperature is maintained between 55° and 75° F., and after hardening sufficiently shall be sprinkled at least three times a day for eight days.

Dimensions. (22). Diameter. The diameter or size of a tile shall refer to the inside diameter and be uniform in all directions. Tile with a diameter of more than thirty (30) inches shall be reinforced.

(23). Thickness. The thickness of the tile wall shall be practically uniform throughout and shall not be less than one-twelfth of the diameter, with a minimum thickness of one-half inch.

(24). Length. The length of a tile shall be uniform at all points with a minimum of 12 inches.

Finished Tile. (25). Finished tile shall be free from such cracks and other defects as will appreciably diminish their strength, and when dry shall give a clear metallic ring when struck with another tile or with a hammer.

Good concrete tile should result from a careful fulfillment of these specifications in all respects excepting that the minimum wall thickness of concrete tile should be 1/10 of the diameter, and specification should be included for each specific case requiring the tile to meet certain strength tests. As a guide in the testing of tile, the Standard Specifications as proposed by the Engineering Experiment Station of the Iowa State College are quoted:

STANDARD SPECIFICATIONS FOR TESTS OF DRAIN TILE AND SEWER PIPE.

SPECIFICATIONS FOR STANDARD ABSORPTION TESTS.

1. *Specimens.* The specimens shall be each approximately three inches square, and shall extend the full thickness of the pipe wall, with the outer skins unbroken.

2. *Number of Test Specimens.* Five individual tests shall constitute a standard test, the average of the five and the result for each specimen being given in the report of the test.

3. *Drying Specimens.* Each specimen shall be dried in an oven or by other application of artificial heat, until they cease to lose further appreciable amounts of moisture when repeatedly weighed.

4. *Brushing Specimens.* All surfaces of the specimens shall be brushed with a stiff brush before weighing the first time.

5. *Weighing.* The specimens shall be weighed immediately before immersion, on a balance or scales capable of accurately indicating the weight within one-tenth of one per cent.

6. *Water for Standard Test.* The water employed in the standard absorption test shall be pure soft water, at the air temperature of a room which is artificially heated in cold seasons of the year.

7. *Immersion of Specimens.* The specimens shall be completely immersed in water for a period of 24 hours.

8. *Re-weighing.* Immediately upon being removed from the water, the specimens shall be dried by pressing against them a soft cloth or a piece of blotting paper. There shall be no rubbing or brushing of the specimen. The reweighing shall be done with a balance or scales capable of accurately indicating the weight within one-tenth of one per cent.

9. *Calculation of Result.* The result of each absorption test shall be calculated by taking the difference between the initial dry weight and the final weight, and dividing the remainder by the initial dry weight.

SPECIFICATIONS FOR STANDARD TESTS OF BEARING STRENGTH.

1. *Specimens.* The specimens shall be unbroken, full sized samples of the pipe to be tested. They shall be carefully selected so as to represent fairly the quality of the pipe.

2. *Number of Specimens.* Five individual tests shall constitute a standard test, the average of the five and the result for each specimen being given in the report of the test.

3. *Drying.* The specimens shall be dried by keeping them in a warm, dry room for a period of at least two days prior to the test.

4. *Weighing.* Each dried specimen shall be weighed on a reliable platform scales just prior to the test.

5. *Bedding of Specimen for Test.* Each specimen shall be actually marked, with pencil or crayon lines, in quarters, prior to the test. Specimens shall be carefully bedded above and below in sand for the one-fourth circumference of the pipe, measured on the middle line of the tile wall. The depth of bedding above and below the tile at the thinnest point shall be equal to one-fourth the diameter of the pipe, measured between the middle lines of the tile walls.

6. *Top Bearing.* The top bearing frame shall not be allowed to come in contact with the tile or with the test load. The upper surface of the sand in the top bearing shall be carefully struck

level with a straight edge, and shall be carefully covered with a heavy, rigid top bearing, with lower surface a true plane, made of heavy timbers or other rigid material capable of uniformly distributing the test load without any appreciable bending. The test load shall be applied at the exact center of this top bearing in such a way, either by the use of a spherical bearing, or by the use of two rollers or rods at right angles, as to leave the bearing free to move in both directions. In case the test is made without the use of a machine and by piling on weight, the weight may be piled directly on a platform resting on the top bearing, provided, however, that the weight does not touch the top frame holding the sand, and provided, further, that the weight is piled in such a way as to insure uniform distribution of the load over the top surface of the sand.

7. *Frames for Top and Bottom Bearings.* The frames for the top and bottom bearings shall be composed of timbers so heavy as to avoid any appreciable bending by the side pressure of the sand. The frames shall be dressed on their interior surfaces. No frames shall come in contact with the tile during the test. A strip of soft cloth may be attached to the inside of the upper frame on each side along the lower edge to prevent the escape of sand between the frame and the tile.

8. *Sand in Bearings.* The sand used for bedding the tile at top and bottom shall be washed sand which has passed a No. 8 screen. It shall be dried by keeping it spread out thin in a warm, dry room.

9. *Application of Load.* The test load shall be applied gradually and without shock or disturbance of the tile. The application of the load shall be carried on continuously, and the tile shall not be allowed to stand any considerable length of time under a load smaller than the breaking load.

10. *Calculation of the Bearing Load.* The total breaking load shall be taken as equal to the total top load, including the weight of top frame, sand for top bearing, top bearing timbers, etc., plus five-eighths of the weight of the pipe. This total load shall be divided by the length of the pipe in feet so as to give the bearing strength per linear foot of pipe.

SPECIFICATIONS FOR CALCULATING THE MODULUS OF RUPTURE IN STANDARD TESTS OF DRAIN TILE AND SEWER PIPE

The modulus of rupture for drain tile and sewer pipe shall be computed from the results of the standard test for bearing strength, according to the following rule:

Divide the bearing strength per linear foot by twelve, multiply the quotient by the radius of the middle line of the tile wall expressed in inches, and divide this product by the square of the minimum thickness of the tile wall at top or bottom, also expressed in inches. This quotient will be the modulus of rupture of the pipe expressed in pounds per square inch.

Field Inspection of Tile.—The field inspection of tile should in all cases be sufficiently thorough to include the inspection of all tile before they are placed in the trench. If strength tests are specified, such tests may be conducted upon average samples by the use of a testing machine or samples sent to some State Experiment Station for reports. However, in any case the majority of the tile must be tested independently of testing apparatus and the actual inspection of the bulk of the tile must necessarily be accomplished by improvised methods applied by the field inspector.

The wall thickness and diameters of the tile are matters of measurements, only those apparently egg-shaped tile being necessarily measured for conformance to cross-section requirements.

The hardness of clay tile and extent to which they are burned may be accurately judged by appearance and sound. Only practice and a comparison of the different grades of tile will render an engineer a proficient judge of these tile characteristics. Tile which are damaged by over or improper burning and drying emit a dull sound when hammer-tested. The presence of cracks is also best detected by the sound test, cracked tile emitting a rattling sound when struck with a hammer, instead of a clear ring. The hammer test can only be successfully applied when tile are tested in an upright, loose position, as cracked tile will often ring clearly when lying in a horizontal position, and all tile will sound dead when frozen to the ground in any position or when partially filled or surrounded with earth. The presence of even minor cracks will be indicated when thus tested in a vertical position, and when indicated by the sound may be located and further traced and investigated as to their extent. Concrete tile are generally true to a circular cross-section, and their soundness or life and the presence of cracks may be tested in a manner similar to that applicable to clay tile. Concrete tile which are dead because of improper manufacture and curing may be readily detected, as they will not ring under the hammer test, although all concrete tile which are freshly made or saturated with moisture will sound lifeless under this test, thus rendering their inspection extremely difficult under such conditions. They are best inspected when thoroughly set and in a reasonably dry condition.

APPENDIX

A copy of the instructions to the jury in the trial of a drainage damage case before Judge D. F. Coyle, of Humboldt, Iowa, which lucidly sets forth the basis upon which damages for open drains should be allowed under the Iowa state drainage laws. The main elements of damage would necessarily be considered as the same were the method of procedure under any state law different in detail.

In the District Court of Iowa in and for....................County.
................Term, 19....
..........................Plaintiffs,
vs.
Drainage District No. ......, et al.
Instructions of the Court.

Gentlemen of the Jury:

1.

The Plaintiffs for their claim and cause of action allege that they are the owners of the .... of Sec. ...., and that the Board of Supervisors of Humboldt County has established a Drainage District in which the said land is included and is constructing a drainage ditch across the same and that the plaintiffs will be damaged by the construction of the ditch in the sum of ...., and they therefore ask the said sum as compensation for the construction of the ditch across the said land.

2.

The undisputed evidence shows that the plaintiffs are the owners of the land in question and that a drainge district has been established by the Board of Supervisors in which the said land is included and that a drainage ditch is being constructed across the same, and the sole question for you to determine is the amount of compensation to which the plaintiffs are entitled.

3.

The rules governing a case of this kind are somewhat confusing to the average man but I will do what I can to make them plain to you. In the first place you must not consider any benefits which the ditch may bring to the plaintiffs. Under the law courts and juries are required to exclude from their minds the benefits which come to a land owner when determining the amount of compensation to which he is entitled for the construction of a drainage ditch thru his land. You will therefore look at the matter just as if it was no benefit to plaintiffs and then say what compensation they ought to have.

In the second place the plaintiffs are entitled to compensation not only for the land actually taken in the construction of the drainage ditch but also for any damage the drainage ditch will cause to their land to-wit, the..............of Sec. ....as a whole. You may consider how much land the drainage ditch will take, whether the spoil banks will be a total loss or can be leveled for a reasonable outlay and can be made use of, whether plaintiffs will be deprived of the use of the land permanently or for a season, and the extent to which they will be deprived of it, the condition in which the land will be left, whether it will be less convenient for farm purposes, whether any other or different bridges will be necessary, whether any other or different fences will be necessary, and all other facts and circumstances bearing on the amount of damage done by the drainage ditch to the land or the amount of compensation which the plaintiffs ought to have, as the same may be shown by the evidence, and you may also take into consideration the fact that the drainage ditch will be permanent.

But in the third place and finally the plaintiffs are entitled to the difference between the reasonable market value of the land in question considered as a whole immediately before the construction of the ditch and its reasonable market value immediately after the construction of the same, excluding benefits.

You will therefore determine the reasonable market value of the whole tract to-wit, the whole.....................immediately before the construction of the ditch and the reasonable market value thereof immediately after the construction of the ditch excluding from your minds any benefit the ditch may be to the lands. The difference between the values thus ascertained is the amount which you should allow plaintiffs, and you should allow them no more and no less. And for the purposes of this case you may assume that the drainage ditch ordered is fully completed and constructed and determine the compensation as of this date tho the ditch is not yet fully constructed.

4.

It may be difficult for you to exclude from your minds the benefits to the land in your determination of the amount of damage or compensation you will allow plaintiffs but the law requires it to be done. In the first place it is the requirement of our state Constitution and in the second place the plaintiffs will be assessed and compelled to pay for all benefits in the drainage district proceedings. So the question for your determination may be stated as follows: ''Assuming that the drainage ditch is no benefit to the plaintiffs how much does it impair or lessen the market value of the land as a whole, taking into consideration the amount of land actually taken for the ditch and the effect of the ditch in all other respects upon the value of the land?'' And you will determine this question as instructed in Instruction No. 3.

5.

In this connection you are also told that the title of plaintiffs to the land taken for the ditch is not divested by the ditch proceedings.

The title to the land still remains in the plaintiffs and they still remain the owners of the land covered by the ditch and the spoil banks and can make any use thereof possible to be made which does not interfere with the ditch as a ditch or with the purpose for which it is constructed. The land is simply burdened with the ditch. In other words the Drainage District is forever to have the use of the land for the ditch and for all purposes incident thereto including the right to clean it out if cleaning should be required. But the plaintiffs continue to remain the owners of the land and the holders of title thereto.

6.

In connection with the question as to what compensation should be allowed the plaintiffs for the lands taken for the spoil banks you are told that inasmuch as the title to the lands remains in the plaintiffs the plaintiffs have the right to level the spoil banks if they can be leveled, and to farm the same if they can be farmed, in so far as the leveling and farming of the same will not interfere with the ditch as a ditch and with the purposes for which it was constructed, and you may take this right of the plaintiffs to level the spoil banks and to farm them, if they can be leveled and farmed, into consideration in your deliberations on your verdict. If the spoil banks can be leveled for a reasonable outlay and farmed when leveled and the damage to the farm by reason of the ditch decreased and lessened thereby it is the duty of the plaintiffs to level the same. But if they can not be leveled for a reasonable outlay or if they can not be farmed or made use of when leveled it is not the duty of the plaintiffs to level them. By a reasonable outlay is meant an outlay which the average farmer would think reasonable in the light of the results obtained. And taking into consideration the right of the plaintiffs to level and to farm the spoil banks as heretofore set forth and all other facts bearing on the question of the compensation to be allowed for the land covered by the spoil banks, it is for you to say whether the plaintiffs ought to be compensated on the basis of a total loss of the use thereof or on the basis of a temporary loss. But upon whichever basis you compensate them you will keep in mind that the sum total to be allowed them should be the difference between the reasonable market value of the farm without the ditch constructed and its reasonable market value with the ditch constructed excluding any benefits which may result to the land by reason of the ditch, and you should not consider any betterment in the condition of the land covered by the spoil banks or in its usefulness resulting from its better drainage by the ditch.

As already explained, the plaintiffs are to be compensated for what they have lost and are not to be charged with what they have gained. But they should not be compensated for any more than they have lost and if the spoil banks can be leveled for a reasonable outlay and farmed when leveled to the extent to which they could be farmed prior to the construction of the ditch the plaintiffs should be compensated on this basis and not on the basis of a total loss, but you should not deduct anything from the compensation by reason of the better drainage of the land resulting from the ditch.

From time to time evidence was stricken from the record during the trial of the case, sometimes on motion or objection of the plaintiffs and sometimes on motion or objection of the defendants. You should disregard all evidence so stricken from the record.

7

The burden is on the plaintiffs to establish the amount to which they are entitled by a preponderance of the evidence.

A preponderance of the evidence does not mean simply the greater number of witnesses. It means the evidence which is the more convincing to the mind.

The burden is therefore on the plaintiffs to show by evidence which is more convincing to the mind than the evidence opposed to it that they ought to have a larger amount than the defendant Board contends they ought to have, and you will take the contention of the defendant Board as to the amount they ought to have to be correct and right unless the plaintiffs have shown by evidence which is more convincing to the mind that they ought to have a larger amount. But if they have shown by evidence which is more convincing to the mind that they are entitled to a larger amount than the defendant Board contends they ought to have you will allow the amount thus shown—fixing it at what you believe the preponderance of the evidence to show they ought to have—but not exceeding the amount claimed.

8

In determining the questions submitted to you for your determination you may weigh the evidence and test the truth thereof in the light of common experience and of your own knowledge of our climate and weather conditions and of the course of nature.

9

I give you one form of verdict, as follows:

''We the jury allow the plaintiffs .... dollars.''

You will insert in the blank space left for that purpose the amount on which you agree.

10

You must not return a verdict determined by lot or by chance or by each juror marking down what he thinks ought to be allowed and adding the amounts and dividing the sum total by twelve or by any other similar method. Your verdict should be the result of your honest judgment and should be based upon the evidence and should declare what you believe the evidence shows ought to be allowed the plaintiffs.

11

You will appoint one of your number Foreman and when you have agreed upon your verdict your Foreman will sign the same and you will then return into Court with your verdict.

You are the sole judges of the credibility of the witnesses and of the weight to be given their evidence. In determining these you may take into consideration their appearance and demeanor while on the witness stand; their manner while testifying; their interest, if any, in the result of the trial; their relations to the parties, if any are shown; the reasonableness or the unreasonableness of their several statements in the light of all the evidence; the opportunities of the witnesses to know the facts testified to by them; their knowledge of the subject-matter and things about which they have testified, together with all surrounding facts and circumstances as proven by the testimony.

Finally, gentlemen, give this case your earnest and careful consideration and return into Court a verdict warranted by the evidence and these instructions.

........................Judge.

STANDARD BIDDING FORM FOR CONSENT DRAINS

Bid on specifications for the Consent Drain on Section..........Township ....Range............

To.........................., owner or manager and.............. ...., Engineer; we hereby submit the following bid for trenching, laying of tile, backfilling, and the construction of walls and inlets on the above drain, and agree to enter into a contract and furnish bond in accordance with the bid, plans and specifications if awarded the contract.

Section	Length	Size	Ave.Depth	Price Per Lineal Foot	Total
Main	....	....	....	....	....
Main	....	....	....	....	....
Main	....	....	....	....	....
Br. 1	....	....	....	....	....
Br. 1	....	....	....	....	....
Br. 2	....	....	....	....	....
Br. 3	....	....	....	....	....
Br. 3	....	....	....	....	....

Retaining Wall complete as per plans. ....
........Inlets complete as per plans. ....
Total Bid - - -

Dated this...........day of.......................19....

....

(Standard forms of drainage outlet contract in cases where the drain is located entirely upon the lands of one owner and where the owner is to both construct and maintain the drain.)

DRAINAGE OUTLET CONTRACT

This agreement, made and entered into this......day of.................. 19.. by and between...................................., party of the first part, and....................................., party of the second part, WITNESSETH: That the party of the first part, in consideration of the promises of the party of the second part, hereinafter expressed, agrees to construct and maintain a tile drain extending from a point..................... ....in a ....direction.................... to an outlet at a point..................... To construct the drain of the following sizes: .... To construct the drain in a workmanlike manner and in accordance with the survey and plans of................................., Surveyor. To permit a free outlet into this tile drain to said party of the second part, his heirs, assigns and grantees for all lands naturally draining towards this natural watercourse as indicated on the surveyor's plat. And in consideration of the performance of the above by the first party, said second party agrees to pay said first party the sum of..

It is further agreed that the duty of the first party to maintain said drain shall be binding upon all heirs, assigns, and grantees of the affected lands owned by said first party, and that in case said first party shall fail or refuse to so maintain said drain then said second party (his heirs, assigns, and grantees) shall have the right to enter the lands of said first party and make any necessary repairs. The cost of such repairs shall be and constitute a mechanic's lien against the lands upon which such repairs are made when a certified statement of the costs is filed with the Clerk of the District Court. It is further agreed that this contract shall not be construed to limit the right of the first party to sell and convey outlet privileges for other lands draining towards this natural watercourse.

....

....

STATE OF .... COUNTY, SS.

On this..........day of...........................A. D. 1912, before me ....a Notary Public in and for said County, personally appeared .... to me known to be the identical person.... named in and who executed the foregoing instrument.... and acknowledged that........ executed the same as............ voluntary act and deed.

....

Notary Public.

Note: This contract should in all cases be recorded in the County Recorder's office to insure the rights of future owners.

(Standard form of outlet contract in cases where the drain is located entirely upon the lands of one owner and where the drain is to be constructed by the owner and maintained by the interested parties jointly.)

DRAINAGE OUTLET CONTRACT

This agreement, made and entered into this........day of................ 19.... by and between................................, party of the first part, and....................................., party of the second part, WITNESSETH: That the party of the first part, in consideration of the promises of the party of the second part, herinafter expressed, agrees to construct a tile drain extending from a point............ in a................ direction.................... to an outlet at a point...................... To construct the drain of the following sizes:..............................

....

To construct the drain in a workmanlike manner and in accordance with the survey and plans of.............................., Surveyor. To permit a free outlet into this tile drain to said party of the second part, his heirs, assigns, and grantees for all lands naturally draining towards this natural watercourse as indicated on the surveyor's plat. And in consideration of the performance of the above by the first party, said second party agrees to pay said first party the sum of..

It is further agreed that it shall be the duty of the first party, his heirs, assigns and grantees to maintain said drain in good condition and that...... per cent of the cost of necessary repairs shall be borne by the party of the second part, his heirs, assigns, and grantees, excepting when such repairs are occasioned by the neglect or carelessness of the first party, in which case the total cost of said repairs shall be borne by the said first party, his heirs, assigns, and grantees. That in case said first party, his heirs, assigns, or grantees, should fail to so maintain said drain then said second party shall have the right to enter the lands traversed by said drain and repair the same and a sworn statement of the cost thereof shall be filed in the office of the Clerk of the District

Court and be and constitute a mechanic's lien against the lands upon which such repairs are made which shall be designated in said statement. And if the said second party, his heirs, assigns, and grantees shall fail to pay the said........ per cent of said costs of maintenance when a verified statement of said expenditures has been presented to him, then the filing of said statement in which the lands chargeable with said expense shall be named with the Clerk of the District Court shall be and constitute a mechanic's lien against said lands of the second party which drain towards said natural watercourse and which are charged with said unpaid portion of the expenses as shown by said statement.

It is further agreed that this contract shall not be construed to limit the right of the first party to sell and convey outlet privileges for other lands draining towards this natural watercourse.

....
....
....

STATE OF .... COUNTY, ss.

On this.......... day of......................., A. D. 19...., before me.............................., a Notary Public in and for said County, personally appeared..
to me known to be the identical person.. named in and who executed the foregoing instrument.., and acknowledged that....... executed the same as....... voluntary act and deed.

....
Notary Public.

Note—This contract should in all cases be recorded in the County Recorder's office to insure the rights of future purchasers.

(Standard form of outlet contract in cases where the drain or drains are located upon the lands of several owners.)

The undersigned, owners of land on sections............................
....
....
....
....
for the purpose of draining the said lands, hereby mutually agree that a private drainage district be established as herein provided to include our said lands, or as much thereof as may by survey be found best.

That.............................., Surveyor, be employed to act as engineer throughout the formation of the district and the construction of the drains herein provided for, and his duties shall be to make all necessary surveys, make a plat, profiles and specifications showing details in substantially the same manner as is done in County Drainage Districts; assist in making a division of the costs of the drains among the interested owners and supervise the work of the contractor during the construction of the drains, it being understood that tile drains are to be used for the collection of the water and the conveyance of the same to..
....
....

That all parties hereto shall be bound by the boundaries of the district, the specifications governing the construction of the drain and quality of materials and the location and depths of drains as prescribed by the engineer.

That the main drain and a sufficient number of branch tile lines to furnish each individual owner an outlet be constructed, it being understood that branch tile lines shall not be constructed to the lands of owners not desiring outlets.

That the engineer and the manager chosen as hereinafter stated, acting jointly, shall in such manner as they see fit submit the work required for the successful completion of said drains, for the competitive bids and let the contract for the same to the lowest responsible bidder, and the successful contractor shall be required to execute a contract and to furnish a bond equal to .... per cent of the contract price to insure the successful completion of the contract.

That a property owner interested in this project shall be elected as manager by a majority vote of the parties hereto, whose duties shall be to collect all monies due the district fund from property owners, to assist in the letting of all contracts to buy the materials and receive and pay out all monies necessary for the prosecution of the work and his compensation for such work shall be .... per day and necessary expenses.

That the signers hereto shall elect two entirely and wholly disinterested persons to act with the engineer as appraisers, and said appraisers shall after investigation as to the lands benefited thereby and all expenses and costs thereof assess and apportion among the land owners the cost thereof and decide how much each shall pay. In making the investigation necessary to such appraisal and apportionment said appraisers shall hear all the parties hereto, requesting to be heard, and all evidence offered as to the cost of said improvement and the character of the lands improved and other matters pertinent thereto, at a time and place fixed by said appraisers.

That the division of cost as herein provided for shall be final and all parties shall abide thereby.

That the amounts so appraised and assessed against the aforesaid property owners shall be due and payable into the district fund at the................. .... Bank in cash or bankable notes bearing .... per cent interest as soon as determined by said appraisers, and if not so paid they shall be collected by the manager. Said district fund shall be subject to the check and direction of the manager for payment of claims against the district.

That no tracts of land shall be legally entitled to outlets into the drains herein provided for until the assessments are paid.

The appraisers shall make a list assessing against each government sub-division of land in the name of the owner, the share of the cost of said drain properly chargeable to said tract and each of said assessments so made shall be and constitute a mechanic's lien upon the respective tracts and subdivisions when a verified statement thereof is filed with the Clerk of the District Court and showing said drainage to have been completed and upon payment said liens may be discharged of record by the party filing the same.

In case the main or any branch drain herein provided for becomes obstructed or in any way damaged so as to affect the usefulness of the drain the owner or owners affected may cause the same to be repaired and the costs of such repair shall be paid for by the respective owners of the tracts of land affected in the same proportion as the original costs assessed to the different tracts benefited by said main or branch, unless the need of such repairs is caused by the neglect or carelessness of any land owner or his agent or representative, in which case said owner shall bear the total costs of the necessary repairs.

Any property owner, his heirs, assigns, or grantees whose outlet is impaired by obstruction in the drains herein provided for shall have the right to enter the lands on which repairs are necessary and make the necessary repairs in case the owner of said land refuses to make necessary repairs and the costs in either case shall be collected from the other owners affected by the obstruction in the proportion above provided for.

....

....

STATE OF .... COUNTY, SS.

On this.......... day of...................., A. D. 19...., before me .... a Notary Public in and for said County, personally appeared.. .... to me known to be the identical person.. named in and who executed the foregoing instrument, and acknowledged that.......... executed the same as .... voluntary act and deed.

....

Notary Public.

Note.—This contract should in all cases be recorded in the County Recorder's office to insure the rights of future purchasers.

(Standard form for tile drain contract between land owners and tile contractors.)

This agreement made this.......... day of.................... by and between.................................... of.................... County, State of.............................., first party and.................. second party, witnesseth: That in consideration of the contract price hereinafter specified to be paid by first party, second party hereby agrees to do all work, furnish all material and pay all expenses in the performing and carrying out of the construction of the drains including the excavation, the laying of tile and such filling of ditches as by the specifications are required by the above named drainage system, in compliance with the specifications, maps and profiles relating to the said work now on file in the office of..........................., Engineer, and will complete the same within the time fixed by the specifications of the party of the first hereby expressly made a part of this contract.

And the party of the second part hereby covenants to do said work at the following prices per lineal foot of drains, as set forth in the bid therefor:

....

....

....

....

....

....

....

....

....

....

....

PAYMENTS

Payments will be made as follows: 80 per cent at the end of each month for the work satisfactorily completed the preceding month and the balance upon the completion of the work and its acceptance by the engineer.

And it is further covenanted that the party of the first part shall not be responsible for delays, loss or damage not directly caused by the express official order of the said party of the first part made after the execution thereof and the second party shall cause no unnecessary inconvenience or damage to the property owners in prosecuting said work.

CHANGING DIMENSIONS

If it shall become apparent to the engineer in charge of the work, that the dimensions of the ditch or drain should be enlarged, deepened or otherwise changed for the better service of the land benefited, the party of the first part may authorize such change in the dimensions of the said improvement and require them to be made and the party of the second part shall, if such change require additional labor or material, undertake to perform such additional work and construction so authorized by the party of the first part at the same terms and price as hereinbefore provided, or at the rate of cost of similar work in the vicinity if such terms or price are not set forth and if a saving of cost results from such a change then the sum saved shall be deducted from the contract price.

FAILURE TO PROSECUTE WORK

If the second party shall fail to prosecute the work according to the specifications, or shall fail or refuse to continuously prosecute the work after commencing the same, and damage to the ditch or district results therefrom, the second party shall be liable therefor, and the first party may recover such damage by action on the bond of the second party; or, the said party of the first part may retain from the amount otherwise due the party of the second part, from time to time, such sum as shall reimburse the party of the first part for such damage, or enable him to repair the same.

ABANDONING WORK

In case the party of the second part shall abandon the work or fail to make satisfactory progress on said work, said first party may cause said work to be completed, and the party of the second part and the sureties on the bond herein referred to, shall be jointly and severally liable to the party of the first part for any and all loss or damages resulting from such default, either from the greater expense of so completing said work, or from any other cause.

SUB-LETTING

It is further agreed by the said party of the second part that he will give his personal attention to the faithful prosecution of the said work, and will not assign or sub-let the same or any part thereof, without the previous written consent of the party of the first part, subject to such conditions for his own protection, as he may see fit to impose.

REVOKING CONTRACT

The party of the first part may stop the work, or revoke this contract, or both, if the party of the second part, or his employes shall wilfully refuse to comply with any of the terms and requirements hereof, in which event the party of the second part shall forfeit to the party of the first part all payments due or to become due on said work, as damages, for such breach of contract, and shall be liable for any further damages by reason thereof, and the party of the first part shall be in no manner liable for so stopping the work or revoking the contract.

CONSTRUCTION

The party of the second part shall keep ditch constructed by him in good condition and repair at his own expense until the same is finally accepted by the party of the first part. The party of the second part covenants to complete said work to the entire satisfaction of the engineer of the first party. Party of the second part shall be liable for all damages occasioned by the negligence or incompetency of his agents or servants.

Should there be any difficulty betwen the parties hereto as to the construction of any of the terms or provisions of this agreement, including the plans and specifications hereinbefore made a part hereof, relating to the work to be done, such differences shall be referred to the engineer employed by the party of the first part in charge of the work, and his decision shall be final and binding upon both parties.

The faithful performance of the terms of this contract by the party of the second part, is further secured by bond.

DAMAGES

It is further understood and agreed by and between the parties hereto that where said proposed improvements herein shall cross any public highway the second party shall take all precautions to prevent accidents occurring to the public and shall protect all excavations with proper signals and warnings; second party shall be responsible for all damages resulting from his negligence in failing to so guard said work, either in a public highway or anywhere else along the course of the said proposed ditch.

In witness whereof the respective parties have hereunto set their hands this .... day of..........................., 19.....

....

....

TABLE XXI—HISTORICAL RECORD OF REPRESENTATIVE TILE DRAINS

Project	Length	Size of Tile	Av. Depth	Grade per 100 Ft., Per Cent	No. of Acres in Watershed	No. of Years Constructed	Nature of Topography	Kind of Tile Used	Extent of Surface Run-off	Has Capacity of Tile Been Sufficient?	Were Surface Inlets Provided?	Nature of Soil in Trench	Have Repairs Been Necessary?	Remarks
1	3000'	18"	5.0'	.10	1200	3	Watershed slopes 3' to 10' per mi.	Glazed Clay	Very Little	No	No	Loam and clay with sand pockets	Inlets provided later	Pond empties in 3 to 5 days after 4" rains
1	7000'	16"	7.8'	.10	900	6	80-A pond at upper end—W. S. slopes 5-10' per mi.	"		"	"		No	
2	9000'	20"	6.4'	0—40=.16 40—60=.14 60—90=.10	1300	6	W. S. slopes 15 to 20' per mi.; 30-A pond at source.	Cement	Considerable for lower half, very little for upper half	"	Yes	Sand clay and loam	"	
3	2400'	26"	4.0'	.04	1550	3	W. S. slopes 10' per mi.	Glazed Clay	Large per cent carried in road ditches	Reasonably so	No	Loam clay	"	
3	2400'	22"	5.8'	.16	1300	3	"	"	"	"	"	"	"	
3	1700'	16"	5.5'	.37	900	3	"	Vitrified Clay	Very Little	"	"	Loam clay and gravel	"	
3	4200'	18"	8.2'	.06	800	3	"	"	"	"	"	Loam clay and sand	"	
3	1300'	15"	7.4'	.08	300	3	Flat and swampy	"	"	"	Yes	"	"	
4	2000'	18"	6.5'	.12	500	3	20-A pond at source; W. S. slopes 15' per mi.	"	"	Doubtful	"	"	"	
5	4500'	18"	5.4'	0—10=.40 10—27=.02 27—45=.20	200	3	20-A pond at source; W. S. slopes 20' per mi.	Hard-burned Clay "	Good for lower half, very little for source	Reasonably so	No	Loam and clay with sand pockets	"	
					750	3	W. S. slopes 10-15' per mi.	Cement	Very little	Yes	"	"	"	
6	2500'	22"	5.0'	.07			Main draw flat and swampy.	"	"	"	"	"	"	
6	2700'	20"	8.0'	.07	600	3	"	"	"	"	"	"	"	
7	1100'	12"	4.5'	.20	200	3	"	"	Good	Reasonably so	Yes	"	"	
8	2000'	24"	5.5'	.34	2020	2	Watershed mostly flat and swampy	"		"	"	"	"	
8	2700'	26"	7.6'	.10	1820	2	"	"	"	"	"	"	"	
8	2700'	24"	7.7'	.12	1500	2	"	"	Very little	"	"	"	"	
8	2100'	22"	7.3'	.11	1200	2	"	"	"	"	"	"	"	
8	2700'	20"	8.6'	.10	650	2	"	"	"	"	"	"	"	
8	3200'	16"	8.9'	.10	400	2	"	"	"	"	"	"	"	
9	2400'	22"	5.4'	.08	1100	3	W. S. slopes 20' per mi.; main draw flat	Glazed Clay	"	"	No	Loam, clay, boulders and sand pockets	"	Tile laid by machine
9	1150'	20"	6.4'	.06			"	"	"	"	"	"	"	"
9	1000'	18"	5.4'	.06	900	3	"	"	"	"	"	"	"	"
10	1300'	20"	5.5'	.15	650	3	"	Vitrified Clay	"	"	"	Loam, clay and sand	10 ft. tile found broken and relaid	Tile probably broken by pressure of machine
10	4100'	18"	5.1'	13—40=.24 40—54=.17	1240	4	W. S. Slopes 15 to 20' per mi.	"	Good	Doubtful	"	Loam, clay and sand pockets		
					900	4	"	"	"	"	"	"	No	
10	3700'	18"	4.8'	.17	900	4	W. S. slopes 5-10' per mi.	"	Very little	"	Yes	"	"	
11	2700'	20"	6.1'	.09	750	3	W. S. slopes 20' per mi.	Glazed Clay	Good	Yes	"	Stiff clay and loam	"	
11	1900'	18"	7.4'	.09	350	3	"	"	Very little	"	"	Loam, clay and sand pockets	"	
11	1100'	14"	6.6'	.09	140	3	"	Hard-burned Clay	"	"	"	"	"	
12	1000'	12"	4.5'	.16	140	3	"	"	Good	"	"	"	"	
12	2000'	10"	4.5'	.60	110	3	W. S. slopes 20 to 30' per mi.	"	"	"	"	"	"	
13	700'	14"	5.0'	.08	220	2	Flat slopes 5 to 10' per mi.	Glazed Clay	"	"	"	"	"	
13	2200'	15"	6.1'	.12	200	2	"	"	Very little	"	"	"	"	
13	900'	12"	6.5'	.12	160	2	"	Vitrified Clay	"	"	"	"	"	
14	1100'	22"	5.0'	.20	1440	2	Slopes 10-15' per mi	Glazed Clay	Good	Doubtful	"	Loam, clay and sand	"	Main draw damaged too much by flood waters
14	7000'	20"	5.2'	.20	1100	2	"	"	"	"	"	"	"	" " "
15	10000'	22"	5.2'	.20	2280	2	Slopes 20-30' per mi.	"	"	No	"	Loam and clay	"	
15	6300'	18"	6.2'	.12	1000	2	Slopes 10-15' per mi.	"	Fair	Doubtful	"	"	"	

TABLE XXII.—HISTORICAL RECORD OF REPRESENTATIVE OPEN DRAINS

Project	From Sta.	To Sta.	Base Width	Av. Depth	Side Slopes	Fall per Mi.	Watershed Area	Nature of Watershed	No. of Years Constructed	Nature of Soil
1	0	203	8′	6.6′	1 to 1	See Profile	10080-A	Flat valley. Watershed slopes 15 ft. per mi.	1	Loam and clay with sand pockets
1	203	285	6′	9.3′	"	"	7400-A	"	1	"
1	285	383	4′	6.5′	"	"	3300-A	"	2	"
2	0	41	8′	6.1′	"	"	4380-A	Average watershed slopes 10′ per mi.	½	Loam and clay
2	41	86	6′	9.9′	"	"	3380-A	"	1	Loam and clay with sand pockets
2	86	144-150	4′	8.8′	"	"	2000-A	"	1	Loam and clay
3	0	211	4′	7.0′	0-140=1½ to 1 140-211=1 to 2	0-140=2.5′ 140-211=3.5′	4700-A	Flat slopes=5-8 ft. per mi.	4	Black loam and clay
4	0	45	4′	5.5′	1 to 1	1.5′	640-A	Large pond, a long ditch; steep W. S. slopes	4	Muck and peat over clay
5	0	370	6′	7.0′	"	4.0′	8000-A	Watershed slopes 5 to 10 ft, per mi.	5	Loam and clay with sand pockets
5	370	893	4′	8.0′	"	9.0′	3000-A	"	5	"
6	0	155	8′	10.0′	"	3.5′	6400-A	Watershed slopes 6 ft. per mi.	3	0—100—Clay. 100—155—Sand strata under loam and clay
6	155	170	6′	8.0′	"	"	4000-A	"	3	Peat over clay with sand pockets
7	0	42	4′	8.0′	"	"	500-A	"	3	"
8	0	99	6′	9.0′	"	2.5′	2900-A	Watershed slopes 5 ft. per mi.	4	0—80=Loam and clay 80—99=Peat over clay
8	99	260	4′	8.5′	"	"	1640-A	"	4	99—150=Peat over clay 150—260=loam and clay
9	0	800	10′	10.0′	"	2.3′	18000-A	W. S. slopes 5 to 15 ft. per mi.	7	Loam and clay with sand pockets
9	300	460	8′	9.0′	"	"	10000-A		6	"
10	0	22	3′	5.0′	"	4.0′	1200-A	W. S. slopes 6 ft. per mi.	5	Loam and clay

TABLE XXII.—HISTORICAL RECORD OF REPRESENTATIVE OPEN DRAINS—Continued

Project	Depth Excav. Below Grade	Depth of Fill First Year	Depth of Fill After First Year	Were Ditch Inlets Provided?	Has Capacity of Ditch Proved Sufficient for Flood Waters?	Does Ditch Need Deepening to Provide Satisfactory Tile Drainage Outlets?	Remarks
1	See Profile	See Profile	...	No	Yes	No	Edges were not trimmed upper mile of ditch Edges were trimmed for balance of ditch
1	"	"	...	One	"	200-285, yes	
1	"	"	...	No	"	Yes	
2	"	"	...	Yes	Yes	No	The accompanying photograph illustrates the eroding action of the water upon steep gradients, which action is principally the cause of the filling at the junction of the steep and flat grades
2	"	"	...	"	"	"	
2	"	"	...	"	"	"	
3	1 ft.	1 ft.	180—211=1 ft. 0—180=0 ft.	No	Yes	0-180, no 180-211, yes	Soil exceptionally good for self maintenance
4	2 ft.	2 ft.	1 ft.	"	"	Yes	Ditch clogged with weeds and rubbish
5	2 ft.	2 ft.	...	"	No	"	Serious filling because of ragged ditch edges and lack of ditch inlets
5	2 ft.	2 ft.	...	"	Yes	No	"
6	0—100=2' 100—155=0'	0—100=1 ft. 100—155=5 ft.	...	One 2d year	"	Yes	Dredge was passed over 100-155 as often as possible. Sand flowed in as rapidly as removed
6	1 ft.	1 ft.	1 ft.	No	"	"	
7	1 ft.	2 ft.	1 ft.	"	"	"	Ditch readily fills with weeds and rubbish
8	1 ft.	0—80=1' 80—99=1.5'	...	"	"	No	80 to 90 was cleaned twice by the dredge during construction because of inflow of peat
8	1 ft.	2'	...	"	No	Yes	Same as above for 99-150
9	0	2'	...	"	0-100—No, too shallow, 6 ft. depth	"	Ditch has eroded slightly after conclusion of filling action
9	0	1 ft.	1 ft.	"	Yes	No	
10	0	...	...	"	"	Yes	Ditch clogged with weeds and rubbish. See accompanying profile for fill during 5 years. Ditch is outlet for 18" tile drain

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